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IN-FLIGHT INVESTIGATION OF LONGITUDINAL SHORT-PERIOD HANDLING CHARACTERISTICS OF WHEEL-CONTROLLED AIRPLANES

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Cornell Aeronautical Laboratory, Inc.

TECHNICAL REPORT AFFDL-TR-68-91

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Prepared for

AIR FORCE FLIGHT DYNAMICS LABORATORY
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FOREWORD

This report was prepared for the United States Air Force by the Cornell Aeronautical Laboratory, Inc., Buffalo, New York in partial fulfillment of Contract AF33(615)-3294.

The program was performed by the Flight Research Department of Cornell Aeronautical Laboratory under the sponsorship of the Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio as Task No. 821905 of Project 8219. Major William Smith (FDCC) was project officer for the Flight Dynamics Laboratory.

This report is also being published as Cornell Aeronautical Laboratory Report No. BM-2238-F-5. The work reported in this document represents the efforts of a group of individuals including: Mr. Franklin Eckhart and Mr. Nello Infanti the evaluation pilots; Mr. Dennis Behm who helped in the setting up of the configurations and the reduction of the data; and Mr. R. Huber, who was responsible for the modifications, calibration and maintenance of the variable stability system. The CAL T-33 Project Manager was R.C. Kidder.

This report was submitted by the author in April 1968.

This technical report has been reviewed and is approved.

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ABSTRACT

The results of an in-flight investigation of the short-period handling qualities requirements for the up-and-away portion of the mission of a wheel-controlled airplane with a low to medium load factor are reported and discussed. Two groups of configurations with constant short-period damping ($\zeta_{sp} \approx .7$) but different n_z/α's and $1/T_{\theta_2}$'s were investigated. A brief study was conducted to determine the effect on the airplane handling qualities of variations in stick motion per normal acceleration and the PIO tendencies resulting from a reduction in short-period damping from $\zeta_{sp} \approx .7$ to $\zeta_{sp} \approx .1$. The results are presented in terms of pilot rating and pilot comment data. Comparisons with the proposed Recommendations for Revision of MIL-F-8785(ASG) "Military Specification - Flying Qualities of Piloted Airplanes" are made and the data is correlated with various suggested short-period handling qualities criteria. The vehicle used for the in-flight evaluation was a three-axis variable stability T-33 equipped with a wheel controller.

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LIST OF SYMBOLS

c , Wing chord, ft.

C , Capacitance, microfarads

$C_L = L/\frac{1}{2}\rho V_o^2 S$, Airplane lift coefficient

$C_{L_\alpha} = \partial C_L/\partial \alpha$, Nondimensional airplane lift curve slope, 1/rad

$C_{L_{\delta_e}} = \partial C_L/\partial \delta_e$, Nondimensional lift coefficient derivative due to elevator control, 1/rad

$C_m = M/\frac{1}{2}\rho V_o^2 S c$, Airplane pitching moment coefficient

$C_{m_\alpha} = \partial C_m/\partial \alpha$, Nondimensional airplane pitching moment curve slope, 1/rad

$C_{m_{\dot\alpha}} = \partial C_m/\partial\left(\frac{\dot\alpha c}{2V_o}\right)$, Nondimensional pitching moment coefficient damping derivative with respect to angle of attack rate, 1/rad

$C_{m_q} = \partial C_m/\partial\left(\frac{qc}{2V}\right)$, Nondimensional pitching moment coefficient damping derivative with respect to angular pitch velocity, 1/rad

$C_{m_{\delta_e}} = \partial C_m/\partial \delta_e$, Nondimensional pitching moment coefficient derivative due to elevator control, 1/rad

$CAP = \omega_{sp}^2/\left(\frac{n_z}{\alpha}\right)$, Control anticipation parameter, $1/sec^2$

$CAP' = \omega_{sp}^2 (\ddot\theta_{nd})_{MAX}/\left(\frac{n_z}{\alpha}\right)$, Control anticipation parameter modified by control system dynamics, $1/sec^2$

F_i Control force of elevator, aileron, or rudder ($i = AW, EW, RP$), lb

g Acceleration of gravity, ft/sec^2

I_x, I_y, I_z Moments of inertia about airplane body x, y, and z axes, respectively, $slug\text{-}ft^2$

I_{xz} Product of inertia with respect to x and z axes, $slug\text{-}ft^2$

$j = \sqrt{-1}$

L Airplane lift, lb

LIST OF SYMBOLS (Cont.)

$L_\alpha = \dfrac{\rho V_0 S}{2m} C_{L_\alpha}$, Normalized lift force derivative with respect to angle of attack, 1/sec

m Mass of airplane, slugs

M Airplane moment, ft-lb

$M_{F_{EW}} = \left(\dfrac{\partial \delta_e}{\partial F_{EW}}\right) M_{\delta_e}$, Normalized pitching moment derivative with respect to elevator wheel force, 1/lb-sec^2

$M_\alpha = \dfrac{\rho V_0^2 S c}{2 I_y} C_{m_\alpha}$, Normalized pitching moment derivative with respect to angle of attack, 1/sec^2

$M_{\dot\alpha} = \dfrac{\rho V_0 S c^2}{4 I_y} C_{m_{\dot\alpha}}$, Normalized damping moment in pitch with respect to angle of attack rate, 1/sec

$M_{\dot\theta} = \dfrac{\rho V_0 S c^2}{4 I_y} C_{m_q}$, Normalized damping moment in pitch due to angular pitch rate, 1/sec

$M_{\delta_e} = \dfrac{\rho V_0^2 S c}{2 I_y} C_{m_{\delta_e}}$, Normalized pitching moment derivative with respect to elevator deflection, 1/sec^2

$M_{\delta_{EW}} = \dfrac{\rho V_0^2 S c}{2 I_y}\left(\dfrac{\delta_e}{\delta_{EW}}\right) C_{m_{\delta_e}}$, Normalized pitching moment derivative with respect to elevator wheel deflection, 1/in.-sec^2

n_z Normal acceleration, g

$\bar q = 1/2 \rho V^2$, dynamic pressure, lbs/ft^2

R Resistance, ohms

s Laplace operator

S Wing area, ft^2

t Time, sec

$\dfrac{1}{T_{\theta_2}} = \dfrac{M_{\delta_e} L_\alpha - L_{\delta_e} M_\alpha}{M_{\delta_e}}$, Numerator lead factor in the constant-speed θ/δ_e transfer function, 1/sec

V Velocity, ft/sec or knots (where so specified)

W Weight, lb

α Angle of attack, radians or degrees (where so specified)

β Angle of sideslip, radians or degrees (where so specified)

δ_i Control surface deflection, in radians, or control wheel deflection, in inches, from trim level flight ($i = a, AW, e, EW, r, RP$)

ζ_i Damping ratio ($i = d, ea, FS, p, SP$)

LIST OF SYMBOLS (Cont.)

θ Pitch angle from trim level flight, deg or rad (where so specified)

ρ Air density, slugs/ft^3

σ Real part of $s = \sigma + j\omega$

τ_α $= -\frac{L_{\delta_e}}{M_{\delta_e}}$

τ_{n_z} $= \pm\sqrt{\frac{L_{\delta_e}}{M_{\delta_e} L_\alpha - M_\alpha L_{\delta_e}}}$

τ_R Roll mode time constant, sec

τ_s Spiral mode time constant, sec

ϕ Bank angle, rad or deg

ω_i Undamped natural frequency ($i = d, EA, FS, p, SP$), rad/sec

ψ Phase angle, deg

$\psi_{\dot{\theta}_{SP}}$ Phase angle of $\dot{\theta}$ response at the short-period frequency, deg

$(\dot{\ })$ $= d(\ )/dt$, First derivative with respect to time, 1/sec

$(\ddot{\ })$ $= d^2(\ )/dt^2$, Second derivative with respect to time, 1/sec^2

Subscripts:

a Refers to total aileron deflection in degrees, positive with right aileron down and left aileron up

AW Refers to aileron wheel deflection at grip in degrees, positive to the right

c Refers to random interference command input to tracking task

d Refers to Dutch roll

e Refers to elevator deflection

ea Refers to elevator actuator

EW Refers to elevator wheel deflection in inches, positive rearward

FS Refers to elevator feel system

MAX Maximum

LIST OF SYMBOLS (Cont.)

Subscripts - Continued

nd	Refers to ratio of pitch angle, pitch velocity, and pitch acceleration, including feel system dynamics, to initial pitch acceleration, excluding feel system dynamics.
p	Refers to phugoid
P_i	Refers to pole location in s plane $(i = 1, 2, 3, \ldots)$
r	Refers to rudder deflection in degrees, positive clockwise when viewed from above airplane
RP	Refers to rudder pedal deflection in inches, right rudder pedal positive
SP	Refers to longitudinal short period
ss	Refers to steady-state values
$STEP$	Refers to step control input
$T\text{-}33$	Refers to basic, unaugmented T-33 airplane
T	True velocity
Z_i	Refers to zero location in s plane $(i = 1, 2, 3, \ldots)$
ϕ	Numerator term in the bank angle to aileron input transfer function
0	Refers to initial value or value at time zero, i.e., denotes reference value

Abbreviations:

CAP	Control anticipation parameter
flt	flight
ft	feet
fps	feet per second
IAS	indicated airspeed
in.	inch
kt	knots

LIST OF SYMBOLS (Cont.)

Abbreviations - Continued

lb	pounds
PIO	pilot-induced oscillation
PIOR	pilot-induced oscillation rating
PR	pilot rating
rad	radians
sec	seconds

SECTION I

INTRODUCTION

The purpose of the investigation reported herein was to examine the longitudinal handling qualities for a selected range of dynamic flight characteristics for an airplane with a low to medium limit load factor utilizing a wheel controller. The parameters varied were n_z/α, ω_{sp} and F_{EW}/n_z.

This experiment was designed primarily to support concurrent work being performed on Reference 1, "Recommendations for Revision of MIL SPEC-F-8785 (ASG) Military Specification - Flying Qualities of Piloted Airplanes." Much work has been done to define the longitudinal handling qualities of airplanes in terms of short-period frequency and more recently in terms of short-period frequency and n_z/α. Unfortunately this work has been divided between low to medium load factor airplanes with wheel controllers operating at low values of n_z/α (max $\approx$ 12) and high load factor fighter type airplanes with center stick controllers operating at high n_z/α's. For this reason the present experiment was conducted to extend the investigation of wheel-controlled airplanes with low to medium load factors to higher values of n_z/α.

This was accomplished by installing a wheel controller in a variable stability T-33 airplane, defining a flight mission compatible with a low to medium load factor airplane and establishing a moderate maximum allowable "g" limit.

In support of Reference 1, the MIL-F-8785 revision, each configuration was evaluated twice. The first evaluation was performed at a fixed value of F_{EW}/n_z. This fixed value was constrained to lie within the F_S/n_z limits of Reference 1 and varied as a function of ω_{sp} according to the results of Reference 2. On the second evaluation, the pilot was allowed to select the value of F_{EW}/n_z he considered to be the optimum. The two results are compared.

Additional objectives of the program were to take a brief look at pilot-induced oscillation (PIO) problems as they relate to a wheel controller and to examine variations in pilot opinion with changes in the wheel motion gradient while holding stick force per "g" constant.

This report includes a detailed description of the experiment, evaluation procedure, test program and equipment used, and discusses the maneuvers performed and the airplane parameters varied. The experimental results are presented in the form of pilot comments and pilot ratings.

SECTION II

TECHNICAL DISCUSSION

To adequately describe the effect of varying any handling qualities parameter, it would be ideal if the effect of the varied parameter could be directly related to the airplane responses the pilot is attempting to control. Although much work has been done to define which longitudinal response, $\dot{\theta}$, n_z or α, is most important in a particular flight regime there still remains considerable controversy as to which is best. Much original longitudinal handling qualities work, References 3-5, attempted to define acceptable longitudinal handling qualities in terms of the longitudinal transfer function denominator characteristics, i.e., assuming constant speed, in terms of short-period frequency and damping. More recent handling qualities research, References 6-10, have shown the importance of the parameters L_α, V and n_z/α as well as ω_{sp} and ζ_{sp}. As indicated in Reference 7, it is equally important to specify desirable numerator characteristics as it is to specify denominator characteristics.

References 5, 8, 9 and 12 indicate that the pitch rate response is of primary importance during low-speed maneuvering and that the control of normal acceleration is of primary importance at high speeds. This leads to the conclusion in References 8 and 9 that the short-period frequency should be a function of L_α at low speeds, (when n_z/α is low), and a function of n_z/α when n_z/α is large. Reference 12 attempts to combine the effects of the pitch rate and normal acceleration responses to a step stick force command that is a weighted sum of both $\dot{\theta}$ and n_z. This combination of responses is further developed in Reference 13 to define a relationship between initial pitch acceleration and steady state normal acceleration. References 10 and 13 relate this parameter to short-period frequency and n_z/α. The present report will show the correlation of the experimental data obtained during this investigation with each of the recommended criteria.

Reference 6 showed through a ground simulator program that a change in true speed at a constant L_α caused a variation in pilot rating. The changes in L_α or $1/T_{\theta_2}$[1] in the present investigation were obtained through a variation in velocity, therefore it is difficult to determine what change is most directly responsible for the variation in pilot rating, i.e., the change in $1/T_{\theta_2}$ or the change in true velocity. Unfortunately, all in-flight variable stability handling qualities data obtained at different values of L_α or $1/T_{\theta_2}$ have used a speed variation to obtain the desired L_α or $1/T_{\theta_2}$ changes. This method being used primarily because of the performance limitations imposed by the large altitude changes required to cause a significant change in ρ. With this in mind, it is worthwhile to look at the constant-speed longitudinal transfer functions as they are affected by variations in $1/T_{\theta_2}$ and/or velocity.

[1]Note: $\frac{1}{T_{\theta_2}} = \frac{M_{\delta_e} L_\alpha - L_{\delta_e} M_\alpha}{M_{\delta_e}}$ when the lift due to the elevator is negligible, i.e. $L_{\delta_e} \approx 0$, $1/T_{\theta_2} = L_\alpha$

The following simplified transfer functions are developed in Appendix I and do not assume that the lift due to elevator deflection, $\mathcal{L}_{\delta_e}$, is negligible:

$$\frac{\dot{\theta}(s)}{\delta_e(s)} = \frac{\mathcal{M}_{\delta_e}(s + 1/T_{\theta_2})}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2}$$

$$\frac{n_z(s)}{\delta_e(s)} = \frac{V}{g}\frac{1}{T_{\theta_2}}\frac{\mathcal{M}_{\delta_e}}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2}$$

$$\frac{\alpha(s)}{\delta_e(s)} = \frac{\mathcal{M}_{\delta_e}}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2}$$

It follows that n_z/α is:

$$\frac{n_z}{\alpha} = \frac{V}{g}\frac{1}{T_{\theta_2}}$$

Time histories have been calculated to show the effect on the longitudinal responses of varying some of the parameters in the above transfer functions. The input was an elevator step with amplitude adjusted to provide the same steady state normal acceleration for each set of responses.

If $1/T_{\theta_2}$ and other factors could be varied without changing velocity so that the α/δ_e transfer function could be kept unchanged, i.e., ω_{sp}, ζ_{sp} and $\mathcal{M}_{\delta_e}$ remain constant, then the n_z/δ_e transfer function would change only by a proportional constant but the $\dot{\theta}/\delta_e$ transfer function would change in phase as well as amplitude since $1/T_{\theta_2}$ appears as a numerator zero. As shown in Appendix I, for a sine representation of the short-period oscillatory roots, the phase angle of the $\dot{\theta}$ response at the short-period frequency can be expressed as:

$$\psi_{\dot{\theta}_{sp}} = \tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^2}}{\frac{1}{T_{\theta_2}\omega_{sp}} - \zeta_{sp}}\right) + \tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^2}}{\zeta_{sp}}\right)$$

The ratio of the maximum pitch rate overshoot to the steady state value can be expressed as:

$$\frac{\dot{\theta}_{MAX}}{\dot{\theta}_{SS}} = 1 - \frac{1}{\sqrt{1-\zeta_{sp}^2}}\sqrt{1 - 2\zeta_{sp}(\omega_{sp}T_{\theta_2}) + (\omega_{sp}T_{\theta_2})^2}\; e^{\frac{\zeta_{sp}}{\sqrt{1-\zeta_{sp}^2}}\tan^{-1}\left[\frac{\sqrt{1-\zeta_{sp}^2}}{\frac{1}{(T_{\theta_2}\omega_{sp})} - \zeta_{sp}}\right]} \sin\left[\tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^2}}{\zeta_{sp}}\right)\right]$$

In the time histories shown in Figure 1, the value of $1/T_{\theta_2}$ has been doubled while holding V, ω_{sp}, ζ_{sp} and $\mathcal{M}_{\delta_e}$ constant. Note that the amplitude of the elevator step input has been adjusted to provide the same steady state n_z response. The

increased angle of attack response required to produce the same n_z response at the lower $1/T_{\theta_2}$ is readily apparent as well as the decrease in pitch rate overshoot for the higher $1/T_{\theta_2}$. The phase shift in the $\dot{\theta}$ response can be observed by comparing the relative difference in time between the two peak $\dot{\theta}$ values. It can also be seen that there is no change in phase in the α and n_z responses. There is also a large change in the initial pitch acceleration.

If it were further possible to vary velocity while holding $1/T_{\theta_2}$, ω_{sp}, ζ_{sp} and M_{δ_e} constant, there would be a change in the relative magnitudes of the α and $\dot{\theta}$ responses with respect to the n_z response. The magnitude changes are proportional to the velocity change.

The time histories in Figure 2 show the effect of doubling the velocity while holding $1/T_{\theta_2}$, ζ_{sp} and ω_{sp} constant and adjusting the elevator step input to normalize the steady state n_z response. Thus the only effect of a change in velocity under these conditions is to change the relative magnitudes of the responses with respect to each other and does not affect their shape or phasing.

Since it was necessary in this experiment to vary the velocity to change $1/T_{\theta_2}$, it is necessary to consider the combined effects that changes in velocity and $1/T_{\theta_2}$ have on the responses. The time histories in Figure 3, which are normalized with respect to the steady state n_z response, show the combined effect of doubling the velocity and $1/T_{\theta_2}$ while holding ζ_{sp} and ω_{sp} constant. We can conclude that a change in velocity and $1/T_{\theta_2}$ at a constant short-period frequency and damping ratio results in three major changes. The amplitudes of the various responses are changed with respect to one another, the ratio of $\dot{\theta}_{MAX}$ to $\dot{\theta}_{ss}$ is changed and the phasing of the pitch rate response with respect to the other responses is changed. Thus for a constant short-period frequency and damping ratio, the phase relationship of the responses will vary only as a function of $1/T_{\theta_2}$. Also the initial value theorem (Appendix I) can be used to show that for a step input $\ddot{\theta}_0/\delta_e = M_{\delta_e}$. Thus when normalizing with respect to n_z steady state, a change in velocity directly affects the sensitivity of the longitudinal response, and correlating flight test data with $\ddot{\theta}_0$ to some extent accounts for the change in velocity.

With this background, consider the effect a change in short-period frequency will have on each of the transient responses while holding the damping ratio, $1/T_{\theta_2}$ and velocity constant. The time histories in Figure 4 show the effect of doubling the short-period frequency while holding ζ_{sp}, $1/T_{\theta_2}$ and V constant and normalizing with respect to n_z steady state. It can be seen that the pitch rate overshoot has changed quite markedly and, though not so obvious because of the change in period, the phasing of the $\dot{\theta}$ response has changed but not those of the α and n_z responses. The initial pitch acceleration has also changed. Thus a change in short-period frequency at a constant $1/T_{\theta_2}$, ζ_{sp} and velocity results in a change in phase of the $\dot{\theta}$ response with respect to the other responses and a change in the ratio of $\dot{\theta}_{MAX}$ to $\dot{\theta}_{SS}$.

If we consider for the moment that the pilot is a linear controller, then he is capable of compensating for the changes in velocity that occur at a constant $1/T_{\theta_2}$, ω_{sp} and ζ_{sp} by adjusting his gain; however, he cannot compensate for the change in the phasing of the $\dot{\theta}$ response that results from a change in $1/T_{\theta_2}$ by changing his gain only. Since a change in ω_{sp} at a constant $1/T_{\theta_2}$ and ζ_{sp} does result in a shift in the phase of the $\dot{\theta}$ response, it is possible that, for a change in $1/T_{\theta_2}$, the pilot will find as optimum the short-period frequency that gives the desired phasing of the responses.

Consider the results of selecting a short-period frequency that results in the same phasing of the responses at a different $1/T_{\theta_2}$ but at the same damping ratio. The transient responses in Figure 5 which are normalized with respect to n_z steady state show the effect of doubling $1/T_{\theta_2}$, ω_{sp} and V while holding ζ_{sp} constant. It can be seen that each of the responses has the same shape, that the initial pitch accelerations are the same, that the ratio of $\dot{\theta}_{MAX}$ to $\dot{\theta}_{SS}$ is a constant and, although it is less obvious, the phasing of the responses is the same. This means that, at a constant short-period damping ratio, a constant value of $\omega_{sp} T_{\theta_2}$ insures that two of the important characteristics of the $\dot{\theta}$ response ($\dot{\theta}_{MAX}/\dot{\theta}_{SS}$ and $\psi_{\dot{\theta}_{sp}}$) will be constant. Since the phase angle of the $\dot{\theta}$ response includes the effects of ω_{sp} , ζ_{sp} and $1/T_{\theta_2}$, this would possibly allow short-period frequency requirements as a function of ζ_{sp} and $1/T_{\theta_2}$ to be expressed in terms of an optimum phase angle of the $\dot{\theta}/\delta_e$ transfer function at the short-period frequency. Unfortunately this experiment was conducted at a constant short-period damping ratio so that only those conclusions that apply to a constant damping ratio can be reached.

SECTION III

DESCRIPTION OF THE EXPERIMENT

3.1 TEST PROGRAM

The primary purpose of this test program was to study the effects of $1/T_{\theta_2}$ and V_0, or n_z/α, on the longitudinal short-period handling qualities for a low to medium load factor airplane with a wheel controller.

The short-period investigation was accomplished by varying the longitudinal short-period frequency at a constant damping ratio ($\zeta_{sp} \approx .7$) for two values of n_z/α (16.5 and 56.2). The handling qualities were evaluated by two different evaluation pilots in a variable stability T-33 airplane equipped with a wheel controller.

The variation in n_z/α was obtained by flying the T-33 variable stability airplane at two different indicated airspeeds at 5500 feet pressure attitude. As shown in Appendix II, n_z/α and $1/T_{\theta_2}$ are functions of weight as well as airspeed. Therefore, speed variations were made as fuel was consumed to keep the values of n_z/α and $1/T_{\theta_2}$ within acceptable bounds. The average indicated airspeeds were 225 knots and 372 knots, corresponding to true airspeeds of 411 ft/sec and 685 ft/sec respectively. The minimum n_z/α (16.5) used was determined by the minimum speed at which the T-33 could pull 2 g's without entering stall buffet. The maximum n_z/α (56.2) used in this experiment was determined by the maximum speed at which sufficient thrust was available for maneuvering.

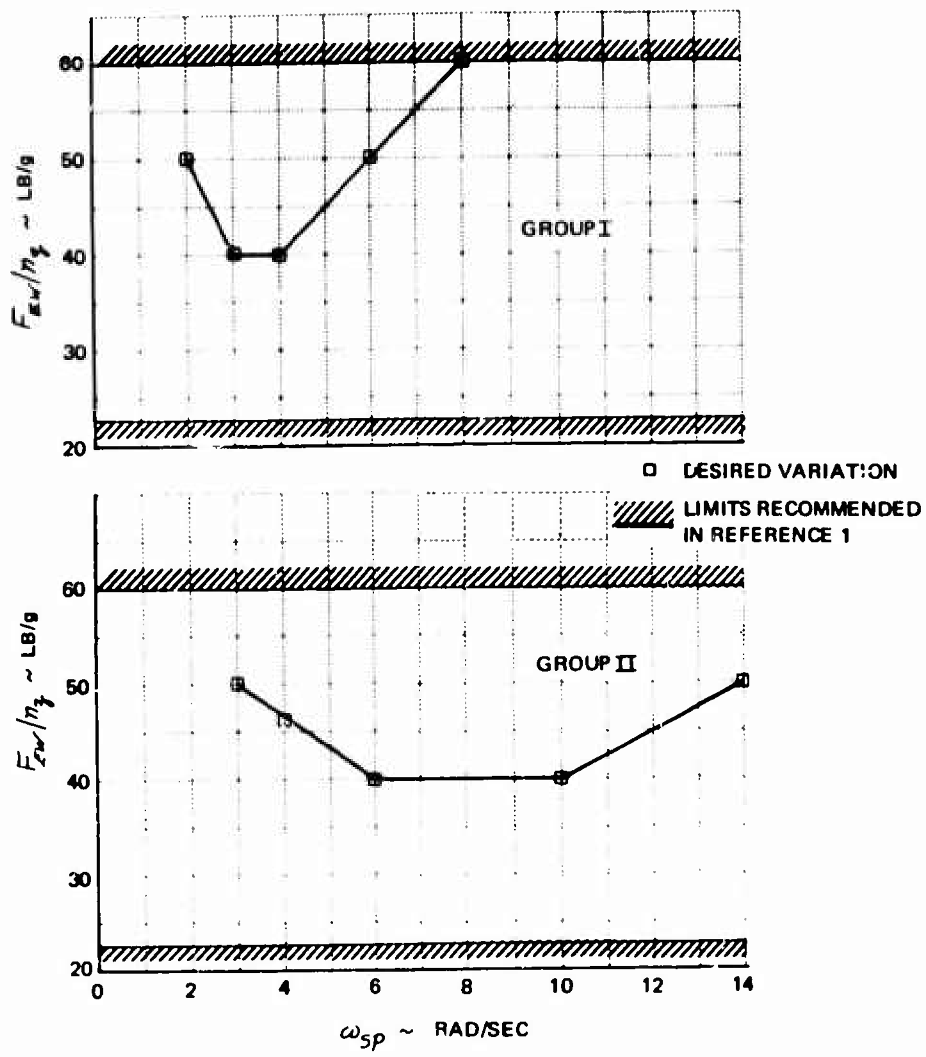
At the low n_z/α (16.5), the short-period frequency was varied from 2 rad/sec to 8 rad/sec. At the high n_z/α (56.2), the short-period frequency was varied from 3 rad/sec to 14 rad/sec. The limitations on the natural frequencies which could be obtained were determined by the limitations on the elevator gain settings. The variations in damping ratio from a nominal ζ_{sp} of 0.7 were primarily a function of the accuracy with which the variable stability gain setting could be estimated to keep the damping and frequency constant as a function of fuel remaining.

The two groups of configurations evaluated had the following nominal characteristics:

Group	$n_z/\alpha\ (\frac{g}{rad})$	$V_T\ (\frac{ft}{sec})$	$1/T_{\theta_2}\ (sec^{-1})$	ζ_{sp}	$\omega_{sp}\ (rad/sec)$
I	16.5	411	1.29	0.7	2 to 8
II	56.2	685	2.65	0.7	3 to 14

The flight program was conducted in essentially two parts. Each configuration was evaluated at a fixed value of F_{EW}/n_z. This fixed value was constrained to lie within the F_{EW}/n_z limits of Reference 1 and varied as a function of short-period frequency according to the results of the experiment

in Reference 2. The desired variation is shown below:



The evaluation pilot was then given the opportunity to select the F_{EW}/n_z he considered to be optimum and evaluate the configuration a second time. The value of δ_{EW}/n_z was held constant at 1 in./g.

Two additional in-flight experiments were performed. One was a brief study of PIO problems that result for a low value of short-period damping. This was accomplished by having one evaluation pilot evaluate three different short-period frequencies at the low n_z/α and three at the high n_z/α, for a short-period damping ratio of 0.1. Each of these configurations was evaluated twice, once at a fixed F_{EW}/n_z and then again at the F_{EW}/n_z selected by the evaluation pilot. The second additional experiment was a study of how variations in wheel motion, while holding wheel force per "g" constant, affected the short-period handling qualities. This was accomplished by taking a "good" low n_z/α configuration that had been evaluated at 1 in./g and evaluating it at 2, 3, and 4 in./g.

A set of "good" lateral-directional characteristics was selected for the Group I configurations and a different but equally "good" set for the Group II configurations. These characteristics were held constant within the variations caused by fuel remaining (i.e., no attempt was made to correct the lateral-directional characteristics as fuel was used). The following nominal lateral-directional characteristics were used:

Group I	Group II
$\omega_d \approx 2.77$ rad/sec	$\omega_d \approx 2.65$ rad/sec
$\zeta_d \approx .14$	$\zeta_d \approx .18$
$\omega_\phi \approx 2.66$ rad/sec	$\omega_\phi \approx 2.50$ rad/sec
$\zeta_\phi \approx .13$	$\zeta_\phi \approx .19$
$\left\lvert \frac{\phi}{\beta} \right\rvert_d \approx 1.19$	$\left\lvert \frac{\phi}{\beta} \right\rvert_d \approx 1.85$
$\tau_R \approx .74$ sec	$\tau_R \approx .22$ sec
$\tau_S \approx 70$ sec	$\tau_S \approx 23$ sec

The following lateral-directional feel system characteristics were also held constant for both groups evaluated:

AILERON	RUDDER
$\omega_{FS} = 25$ rad/sec	$\omega_{FS} = 25$ rad/sec
$\zeta_{FS} = 0.70$	$\zeta_{FS} = 0.70$
$\frac{F_{AW}}{\delta_{AW}} = .42$ lb/deg	$\frac{F_{RP}}{\delta_{RP}} = 120$ lbs/in.

3.2 EVALUATION PROCEDURE

The short-period handling qualities investigation was conducted with two evaluation pilots. Because the selection of F_{EW}/n_z was to be an important part of the evaluation program, it was advisable to have two pilots with varied experience to participate in this part of the experiment. Since each pilot evaluated the same configurations, the pilot ratings could be compared directly. The flight experience of the evaluation pilots is summarized below.

Pilot A - Cornell Aeronautical Laboratory Evaluation Pilot with extensive engineering and in-flight demonstration experience in variable stability airplanes. The majority of his flight experience of 4050 hours has been in low to medium load factor multi-engine airplanes.

Pilot B - Cornell Aeronautical Laboratory Evaluation Pilot with extensive experience as an evaluation pilot in handling qualities investigations employing variable stability airplanes and ground simulators. His flight experience of 4500 hours includes over 2000 hours in low to medium load factor multi-engine airplanes. However, the majority of his diversified flight experience has been in fighter type airplanes.

Since large-airplane characteristics were being simulated in a small airplane equipped with a wheel controller, it was necessary to clearly define the airplane mission requirements before any meaningful evaluation of the handling qualities could be accomplished. The airplane evaluated was considered to have a low to medium load factor (+3 g), to be flown with a wheel controller, and to be in the 50,000 to 100,000 lb category. The mission was expected to include many hours in straight and level flight with the possibility of straight and level or small-angle (10° maximum) dive bomb deliveries. It was expected that the airplane would be able to fly formation well enough to permit air-to-air refueling and maneuverable enough to perform low altitude terrain following. The airplane should also be able to perform the reconnaissance mission, which requires precise altitude and airspeed control. It was considered as possibly a multi-manned airplane but perhaps with only one pilot, which would mean that the pilot would have to perform more cockpit duties than in a multi-piloted airplane. The mission as described above was discussed at length, individually and collectively, with the evaluation pilots to ensure that each pilot was evaluating the configurations for the same mission requirements.

Although the mission involves many tasks, an evaluation of the vehicle handling qualities, regarding their suitability for the mission, can be accomplished by having the evaluation pilots perform a series of maneuvers representative of those tasks anticipated in the mission. The representative tasks employed in this evaluation program included only the up-and-away maneuvering requirements for the mission in visual flight. Tasks not adequately simulated, such as formation flying, in-flight refueling and instrument flying, were assessed on the basis of the evaluation maneuvers performed. The terminal tasks of approach and landing were not included. The piloting tasks used to evaluate the configurations were performed at two nominal flight conditions, 225 knots and 372 knots indicated airspeed at 5500 feet.

The evaluation pilot was instructed to perform the following tasks:

1. Check ability to trim and to perform small perturbation maneuvers about level flight.

2. Pitch attitude tracking - Check ability to acquire and maintain desired attitude within ±10 degrees from level.

3. Check ability to acquire and stabilize on a new altitude.

4. Symmetrical pullups and pushovers - ± 1 incremental "g".

5. Turning flight - constant altitude.
   a. Small bank angles (less than 10°).
   b. Large bank angles (up to 45°).

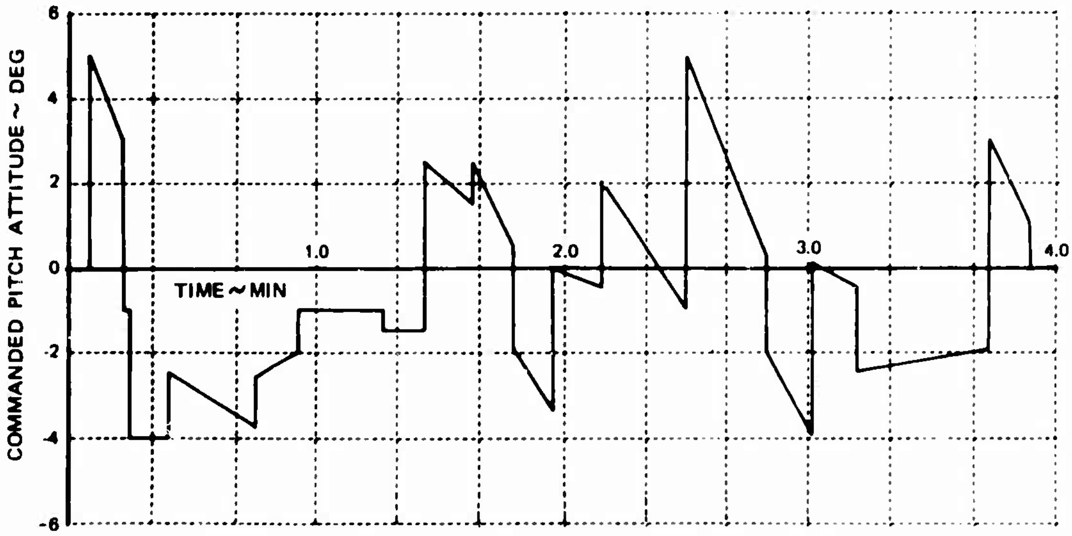
6. Climbing and descending turns.

7. Attitude command tracking tasks.

8. Check handling qualities with disturbance inputs.

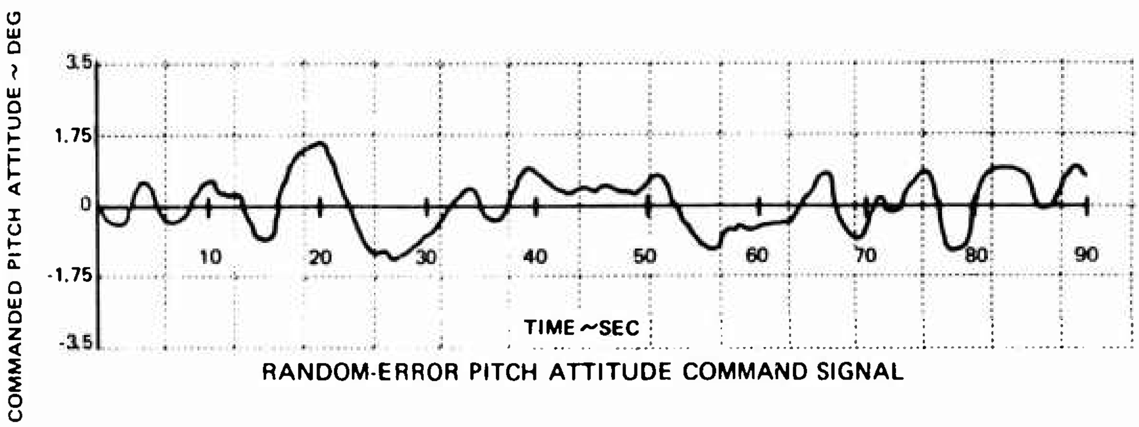
The evaluation pilot performed these maneuvers in order, making comments as he desired on the wire recorder.

Two attitude tracking tasks were used to aid the pilot in his evaluation. The first, or discrete-error, pitch attitude tracking task was mechanized by displaying the error between the actual pitch attitude and a programmed pitch attitude command signal on a horizontal needle in the Lear remote attitude indicator. The pitch attitude command signal is shown in the sketch below, and the attitude indicator in Figure 3. The signal commanded pitch attitudes up to ± 5 degrees, which represented full scale (± 1 inch) deflection of the tracking needle. The attitude changes presented to the pilot were a sequence of step and ramp inputs. This combination of inputs was used primarily to keep the airspeed variations in bounds during the tracking task. To keep the error to a minimum the pilot had to maneuver rapidly and precisely. The duration of the tracking task was controlled by the evaluation pilot; however, the programmed signals repeated every four minutes. This repetition period was considered long enough to prevent the pilot from anticipating the magnitude, direction and time of each succeeding command.



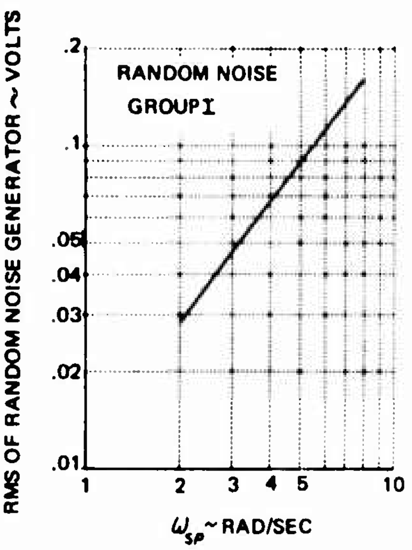
DISCRETE-ERROR PITCH ATTITUDE COMMAND SIGNAL

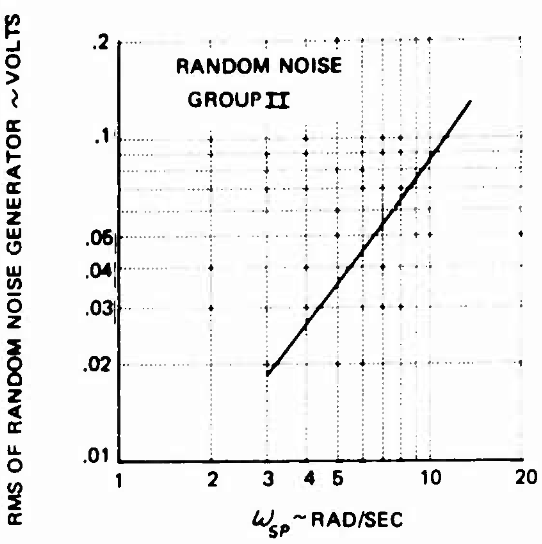
The second, or random-error, pitch attitude tracking task was mechanized by displaying the error between the pitch attitude and that commanded by the random noise signal similar to the one shown below. This task required the pilot to continuously maneuver the airplane to keep the error to a minimum. Maximum pitch attitude commanded was ±3.5 degrees. This value was selected during the calibration phase of the program and remained constant for both groups of configurations.



RANDOM-ERROR PITCH ATTITUDE COMMAND SIGNAL

As part of the evaluation, the pilot was asked to look at the configuration in the presence of random disturbance inputs. The random noise generator described in Section IV was used to supply disturbance inputs to all three control surfaces (ailerons, elevators and rudder). The magnitude of the random input to the ailerons and rudder remained constant but at a different value for the two flight conditions evaluated. The inputs to the elevator were varied as a function of short-period frequency, as shown below. This variation was incorporated because the airplane is more difficult to disturb with the elevator as the short-period frequency of the airplane is increased. During the calibration phase, acceptable magnitudes for the random disturbance were obtained for a number of short-period frequencies and the relationships shown below were developed and used to determine the random input levels to be used at the remaining short-period frequencies. It should be pointed out that the random noise inputs do not and are not intended to simulate realistic atmospheric turbulence. The elevator can only provide pitching inputs and thus cannot provide the heaving motion normally experienced in turbulence. The random noise inputs do provide the pilot with an additional and valuable evaluation aid.





Pilot comments were recorded at any time the pilot felt comments were appropriate and at the end of the evaluation. The pilot was asked for all evaluations to comment on the specific items listed on the Pilot Comment Card, Table I, as well as to make summary comments and to assign an overall pilot rating and a PIO (pilot-induced oscillation) rating to each configuration.

The pilot assigned a PIO rating to the airplane according to the six-point rating scale established in Reference 2 and shown in Table II. The PIO rating has meaning only because of the words associated with it from the rating scale and acts only as a convenient shorthand to discuss the tendency of the airplane toward pilot-induced oscillations.

An overall pilot rating was assigned by the pilot to the configuration in accordance with the ten-point rating scale established in Reference 13 and shown in Table III. This rating included the effects of the random disturbances. Once again, the pilot rating number assigned to a configuration is dependent on the words from the rating scale associated with it. Reference 13 gives an excellent description of the process an evaluation pilot uses to determine a pilot rating. Briefly, the pilot decides whether the configuration is controllable or uncontrollable in the required mission. If it is deemed controllable, it is then assigned to the acceptable or unacceptable category. If the configuration is considered to be acceptable, it is then determined to be satisfactory or unsatisfactory and is further broken down according to the descriptive phrases that most adequately describe the handling qualities. If a configuration is considered to be unacceptable, the pilot is primarily evaluating its controllability in performing the mission.

For both the PIO rating scale and the pilot rating scale, half ratings were used when the evaluation pilot felt that a given configuration did not exactly fit in one of the described categories. As a matter of convenience, the letters in front of the pilot ratings have been dropped when discussing the pilot ratings and on the figures in this report.

The configurations were essentially evaluated in a random manner with normally three configurations evaluated on each evaluation flight. Because of the attempt to keep n_z/α and $1/T_{\theta_2}$ within prescribed limits as the weight of the airplane changed due to fuel usage, a low n_z/α (Group I) configuration was always evaluated first and a high n_z/α (Group II) configuration last. The middle evaluation was randomly a Group I or Group II configuration. The evaluation pilot had approximately 25 minutes for each configuration to perform the necessary maneuvers, make the appropriate comments to accomplish the evaluation, and obtain calibration records.

A short in-flight investigation was conducted to study the effects on the short-period handling qualities and the PIO tendencies that result when the short-period damping was reduced from $\zeta_{sp} \approx .7$ to $\zeta_{sp} \approx .1$. One pilot evaluated three short-period frequencies ($\omega_{sp} \approx$ 2, 4 and 6 rad/sec) at the low n_z/α and three short-period frequencies ($\omega_{sp} \approx$ 3, 6 and 10 rad/sec) at the high n_z/α with $\zeta_{sp} \approx 0.1$. Each configuration was evaluated at the fixed F_{EW}/n_z that corresponded to the n_z/α and ω_{sp} used in the main part of the experiment. This was followed immediately with the F_{EW}/n_z selected by the evaluation pilot.

At the conclusion of the flight program, one flight was devoted to a brief investigation of wheel motion per normal acceleration, δ_{EW}/n_z . This was accomplished by evaluating a "good" low- n_z/α configuration at three different values of δ_{EW}/n_z at a constant F_{EW}/n_z. For this investigation, a Group I configuration with $\omega_{sp} \approx$ 4 rad/sec was evaluated at values of δ_{EW}/n_z of 2 in./g, 3 in./g and 4 in./g. During the primary evaluation, δ_{EW}/n_z had been held essentially constant at 1 in./g.

It is important during any handling qualities investigation to ensure that the various configurations evaluated are adequately identified. To accomplish this, the following in-flight oscillograph records were taken for each configuration that was evaluated:

1. Response to automatic step.

2. Response to manual step.

3. One minute discrete-error pitch attitude tracking.

4. One minute random-error pitch attitude tracking.

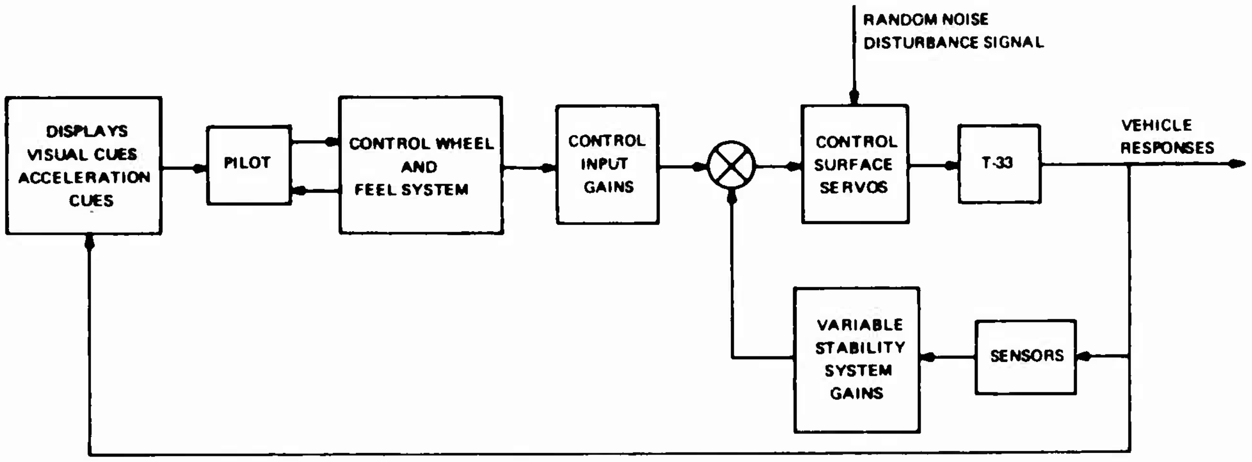
These records were analyzed during and after the completion of the flight test program. Since it is not always feasible to take the time to find the smooth atmospheric conditions necessary to obtain good transient response records on an evaluation flight, the values used to generate the responses presented in this report were selected from calibration and evaluation flights on which these conditions were obtained. However, the transient responses obtained on the evaluation flights were adequate to ensure that the configurations evaluated were set up properly and that the responses presented in this report are representative of those evaluated.

SECTION IV

EQUIPMENT

The evaluations were performed in a three-axis variable stability T-33 airplane modified and operated by the Cornell Aeronautical Laboratory for the Air Force Flight Dynamics Laboratory, Air Force Systems Command. The variable stability equipment is described in Reference 14. The airplane is shown in Figure 6. The variable stability T-33 was further modified for this program to include a wheel controller in the front cockpit.

Briefly, the system operator in the rear cockpit, who also serves as safety pilot, may vary the handling characteristics about all three axes by changing the settings of response feedback gain controls located on his right hand console. The handling characteristics are altered so that the evaluation pilot in the front cockpit has no knowledge as to how the gains are changed. Since the evaluation pilot is only connected electrically to the control surface servos, he does not feel any of the control surface motions due to the variable stability signals. The block diagram shown below illustrates the mechanism of the in-flight simulation:



The wheel controller, as installed for this program, is an NAS 348 wheel which has been modified to include the installation of strain gauges and a control button for variable stability system disengage. The wheel installation and the cockpit dimensions pertinent to its installation are shown in Figure 7.

Control feel to the wheel and rudder pedals is provided by electrically controlled hydraulic feel servos which provide opposing forces proportional to the control wheel and rudder pedal deflections (i.e., a simple linear spring feel system). The aileron and rudder feel system dynamics, spring rates, and friction characteristics were held constant throughout the program. For a complete discussion of the elevator feel system refer to Section V.

The evaluation pilot's instrument panel is shown in Figure 8. The flight instruments used by the evaluation pilot are all standard instruments with the exception of the Lear remote attitude-director indicator, type ARU-2/A. This instrument functions primarily as a normal attitude indicator, but in addition, it presents an indication of sideslip and a pitch attitude tracking task to the evaluation pilot. The sideslip is indicated by a vertical needle that moves horizontally across the face of the attitude indicator. Center position of the needle indicates zero sideslip, and full scale movement of the needle is equivalent to ±4 degrees of sideslip. The pitch attitude tracking tasks are presented to the evaluation pilot by means of a horizontal needle that moves vertically on the face of the attitude indicator. The tracking tasks are described in detail in Section III.

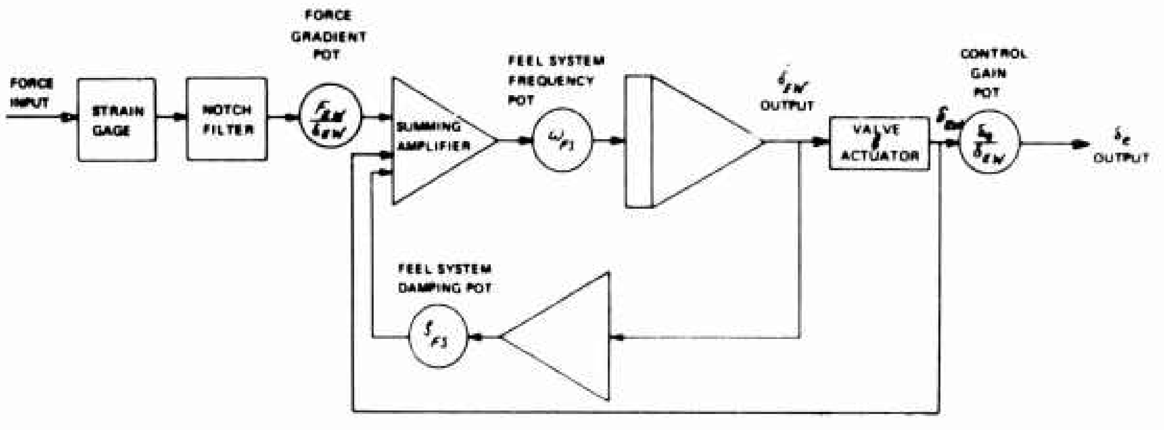
During each of the longitudinal evaluations a random noise source was used to provide an external disturbance to the airplane. Although the random disturbances were not a true simulation of turbulence, they did provide the pilot with an additional evaluation aid. The random disturbances were obtained by driving the T-33 control surface actuators by a random noise signal. The signal was generated by a gas tube white noise source passed through a bandpass filter. The filter has the frequency response shown in Figure 9 with a second-order break point at .1 rad/sec and a second-order break point at 18.8 rad/sec. The amplitudes of the disturbance signals going to the elevator, ailerons, and rudder were varied independently.

SECTION V

ELEVATOR FEEL SYSTEM CHARACTERISTICS

The importance of the attenuation of the feel system and the flight control system actuators on the closed-loop response of an airplane has gained increased recognition in recent handling qualities studies. References 2, 15, and more recently Reference 16, have attempted to describe the contributions of the feel system to the closed-loop airplane response.

The mechanism of the variable stability T-33's elevator feel system is shown below:



The pilot's force input is made through strain gages on the wheel. These inputs pass through a notch filter into the feel servo control network where the frequency and damping of the elevator feel servo are controlled. The result is a positioning of the control column with the gradients, frequency and damping determined by the feel system gain settings. The position of the column is then modified by the δ_e/δ_{EW} gain and used as the δ_e signal for the elevator actuator.

The equation of the notch filter is given below and the frequency response is shown in Appendix III.

$$\frac{E_{out}}{E_{in}} = \frac{s^2 + \frac{1}{R_1^2 C_1^2}}{s^2 + \frac{(4R_1C_1 - 4KR_1C_1)s}{R_1^2C_1^2} + \frac{1}{R_1^2C_1^2}} = \frac{s^2 + 4739}{s^2 + 275.3s + 4739} \qquad (1)$$

The response of the feel system to an elevator wheel force command is then determined by the following transfer function:

$$\frac{\delta_{EW}(s)}{F_{EW}(s)} = \frac{\omega_{FS}^2 \left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS} (s^2 + 4739)}{(s^2 + 2\zeta_{FS}\omega_{FS}s + \omega_{FS}^2)(s^2 + 275.3s + 4739)} \tag{2}$$

For this program: ω_{FS} = 23.0 rad/sec, ζ_{FS} = .66

The δ_{EW} signal generated by the feel system and modified by the δ_e/δ_{EW} gain is applied to the elevator through the elevator actuator. The δ_e/δ_{EW} transfer function can be represented (Reference 14) as:

$$\frac{\delta_e(s)}{\delta_{EW}(s)} = \frac{\omega_{ea}^2 \left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}}{s^2 + 2\zeta_{ea}\omega_{ea}s + \omega_{ea}^2} \tag{3}$$

For this program: ω_{ea} = 63 rad/sec, ζ_{ea} = .70

Thus the angle of attack, pitch rate and normal acceleration responses to a wheel force input can be represented as follows:

$$\frac{\alpha(s)}{F_{EW}(s)} = \frac{\alpha(s)}{\delta_e(s)} \frac{\delta_e(s)}{\delta_{EW}(s)} \frac{\delta_{EW}(s)}{F_{EW}(s)} \tag{4}$$

$$\frac{\dot{\theta}(s)}{F_{EW}(s)} = \frac{\dot{\theta}(s)}{\delta_e(s)} \frac{\delta_e(s)}{\delta_{EW}(s)} \frac{\delta_{EW}(s)}{F_{EW}(s)} \tag{5}$$

$$\frac{n_3(s)}{F_{EW}(s)} = \frac{n_3(s)}{\delta_e(s)} \frac{\delta_e(s)}{\delta_{EW}(s)} \frac{\delta_{EW}(s)}{F_{EW}(s)} \tag{6}$$

Substituting the individual transfer functions shown above into Equations 4, 5, and 6, the following transfer functions result that describe the airplane response to a wheel force input:

$$\frac{\alpha(s)}{F_{EW}(s)} = \frac{\omega_{FS}^2 \omega_{ea}^2 (s^2 + 4739) M_{\delta_e} \left(\frac{\delta_e}{\delta_{EW}}\right)_{SS} \left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS}}{(s^2 + 2\zeta_{SP}\omega_{SP}s + \omega_{SP}^2)(s^2 + 2\zeta_{FS}\omega_{FS}s + \omega_{FS}^2)(s^2 + 2\zeta_{ea}\omega_{ea}s + \omega_{ea}^2)(s^2 + 275.3s + 4739)} \tag{7}$$

$$\frac{\dot{\theta}(s)}{F_{EW}(s)} = \frac{\omega_{FS}^2\, \omega_{ea}^2 \left(s^2 + 4739\right) M_{\delta_e} \left(\frac{\delta_e}{\delta_{EW}}\right)_{ss} \left(\frac{\delta_{EW}}{F_{EW}}\right)_{ss} \left(s + \frac{1}{T_{\theta_2}}\right)}{\left(s^2 + 2\zeta_{sp}\omega_{sp} s + \omega^2\right)\left(s^2 + 2\zeta_{FS}\omega_{FS} s + \omega_{FS}^2\right)\left(s^2 + 2\zeta_{ea}\omega_{ea} s + \omega_{ea}^2\right)\left(s^2 + 275.3s + 4739\right)} \tag{8}$$

$$\frac{n_z(s)}{F_{EW}(s)} = \frac{\omega_{FS}^2\, \omega_{ea}^2 \left(s^2 + 4739\right) M_{\delta_e} \left(\frac{\delta_e}{\delta_{EW}}\right)_{ss} \left(\frac{\delta_{EW}}{F_{EW}}\right)_{ss} \frac{V}{g} \frac{1}{T_{\theta_2}}}{\left(s^2 + 2\zeta_{sp}\omega_{sp} s + \omega_{sp}^2\right)\left(s^2 + 2\zeta_{FS}\omega_{FS} s + \omega_{FS}^2\right)\left(s^2 + 2\zeta_{ea}\omega_{ea} s + \omega_{ea}^2\right)\left(s^2 + 275.3s\ 4739\right)} \tag{9}$$

The subscript ss refers to the steady state gain values or asymptotic values at the low frequencies. Thus the effect of the attenuation of the feel system and elevator actuator on the open-loop response of the airplane can be calculated using the above transfer functions.

One method used to describe the effect of the feel system dynamics on the open-loop airplane response (Reference 2) is to define a nondimensional parameter that represents the ratio of the maximum pitch acceleration including the effects of the feel system dynamics to the initial pitch acceleration without the feel system dynamics for step wheel force inputs.

The pitch acceleration transfer function to a wheel force input at constant speed without feel system or elevator dynamics can be written from Equation (8) as:

$$\frac{\ddot{\theta}(s)}{F_{EW}(s)} = \frac{s\,\dot{\theta}(s)}{F_{EW}(s)} = \frac{M_{\delta_e} \left(\frac{\delta_e}{\delta_{EW}}\right)_{ss} \left(\frac{\delta_{EW}}{F_{EW}}\right)_{ss} s\left(s + \frac{1}{T_{\theta_2}}\right)}{\left(s^2 + 2\zeta_{sp}\,\omega_{sp}\, s + \omega_{sp}^2\right)} \tag{10}$$

For a step wheel force input we can use the initial value theorem to determine the initial pitch acceleration.

$$\ddot{\theta}_0 = \lim_{s \to \infty} \left[s \frac{\ddot{\theta}(s)}{F_{EW}(s)} \frac{F_{EW}}{s} \right] = \lim_{s \to \infty} \left[\frac{\ddot{\theta}(s)\, F_{EW}}{F_{EW}(s)} \right]$$

$$= M_{\delta_e} \left(\frac{\delta_e}{\delta_{EW}}\right)_{ss} \left(\frac{\delta_{EW}}{F_{EW}}\right)_{ss} F_{EW} \tag{11}$$

The actual airplane response including the feel system dynamics can then be normalized by the initial pitch acceleration without feel system dynamics by dividing by the corresponding $\ddot{\theta}_0$. Thus:

$$\dot{\theta}_{nd}(s) = \frac{\dot{\theta}(s)}{M_{\delta_e}\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS} F_{EW}} \tag{12}$$

$$\ddot{\theta}_{nd}(s) = \frac{\ddot{\theta}(s)}{M_{\delta_e}\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS} F_{EW}} \tag{13}$$

For an instantaneously applied step input, the maximum pitch acceleration occurs at the instant of step application if the elevator and feel system dynamics are not included. However, when the elevator and feel system dynamics are included, the maximum pitch acceleration occurs at some finite time after the step application and the initial pitch acceleration is zero. Because of the complexity of the equation defining the time at which maximum pitch acceleration will occur when the elevator and feel system dynamics are accounted for, time histories for each of the responses ($\dot{\theta}_{nd}$ and $\ddot{\theta}_{nd}$) were generated and the maximum values for each were obtained. Thus:

$$\dot{\theta}_{MAX} = \left(\dot{\theta}_{nd}\right)_{MAX} M_{\delta_e}\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS} F_{EW} \tag{14}$$

$$\ddot{\theta}_{MAX} = \left(\ddot{\theta}_{nd}\right)_{MAX} M_{\delta_e}\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS} F_{EW} \tag{15}$$

Plots of ($\ddot{\theta}_{nd})_{MAX}$ are shown in Figure 10 and represent the attenuation of the elevator actuator and feel system dynamics on the $\ddot{\theta}_{MAX}$ response of the open-loop airplane. From these plots it can be seen that the feel system has quite a large effect on the open-loop $\ddot{\theta}_{MAX}$ response to a step input at the high short-period frequencies simulated.

This development assumes that the pilot continues to fly the airplane with step inputs at all frequencies. Experience indicates that piloting techniques change as a function of short-period frequency and $1/T_{\theta_2}$ or n_z/α and thus the marked attenuation of the airplane responses indicated by the prior development may not necessarily be representative of the actual attenuation felt by the pilot. It does, however, serve to show the importance of the feel system in the closed-loop analysis.

The time histories in Appendix IV show the difference in the airplane responses to an elevator step through the elevator servo and an elevator wheel step that includes the elevator and feel system dynamics.

SECTION VI

DISCUSSION OF RESULTS

The objective of the experiment was to evaluate the effect on the pilot's opinion of the longitudinal handling qualities of a low to medium load factor airplane with a wheel control caused by a variation in short-period frequency at a constant damping ratio for two values of n_z/α. The nominal values for the two groups of configurations are shown below:

GROUP	n_z (g/rad)	V_T (ft/sec)	$1/T_{\theta_2}$ (sec^{-1})	ζ_{SP}	ω_{SP}(rad/sec)
I	16.5	411	1.29	0.7	2 to 8
II	56.2	685	2.65	0.7	3 to 14

The variation in $1/T_{\theta_2}$ and n_z/α was obtained by flying the variable stability T-33 at two different true airspeeds at a constant pressure altitude. The variations in short-period frequency were obtained by varying the δ_e/α, $\delta_e/\dot{\alpha}$ and δ_e/q gain settings in the variable stability system. Appendix V gives a more detailed discussion of the in-flight simulation techniques.

Both groups of configurations were evaluated twice; once at a fixed value of F_{EW}/n_z and again at the F_{EW}/n_z selected by the evaluation pilot. The fixed value of F_{EW}/n_z was constrained to lie within the acceptable limits established in Reference 1 and varied as a function of ω_{SP} according to the results of Reference 2. The feel system is discussed in Section V. Wheel displacement per normal acceleration ($\frac{\delta_{EW}}{n_z}$) was held essentially constant at one inch per g.

A set of good lateral-directional characteristics was established for each group and held constant throughout the evaluation program. The characteristics are listed in Section III.

All of the configurations are defined in detail in Appendix IV. Each of the configurations was identified by the analog matching technique described in Reference 17. Briefly, the in-flight oscillograph recordings of the pitch rate and angle of attack responses to an automatic elevator step are matched by the output of an analog computer programmed to compute the pitch rate and angle of attack transfer functions.

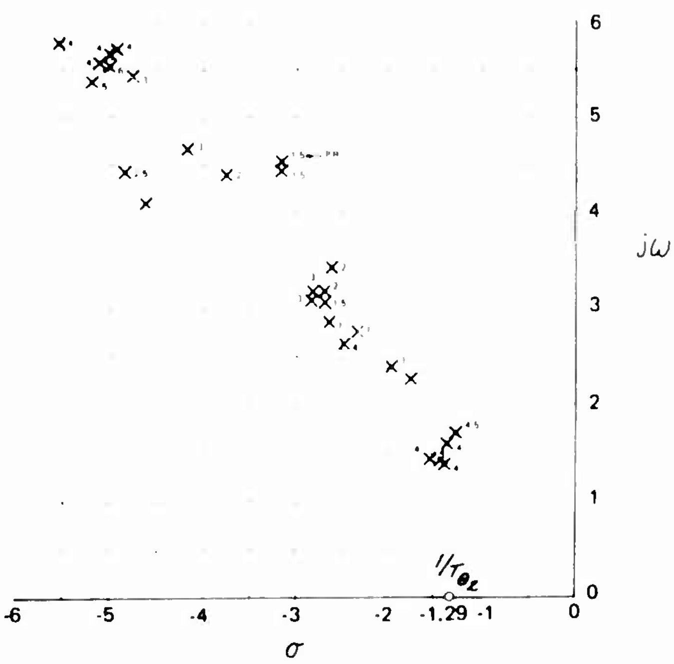
Transient responses are shown in Appendix IV and the pilot comment summaries are presented in Appendix VII. The transient responses were computed in a digital computer using modal characteristics representative of the various configurations evaluated. Two responses are shown for each configuration. One response shows the open-loop airplane response obtained when an automatic elevator step input is applied directly into the elevator servo and

includes the elevator actuator dynamics. The other shows the response that results from a half-inch elevator wheel input and includes the attenuating effects of the feel system and $\frac{\delta_e}{\delta_{EW}}$ gain settings.

The experimental results are discussed in three parts. First the pilot rating variations for a particular group are discussed for both groups and then the variations between groups are examined. Pilot ratings are related to $\omega_{sp}/\frac{n_z}{\alpha}$, CAP, $\ddot{\theta}_{MAX}/F_{EW}$, CAP', $T_{\theta_2}\omega_{sp}$, $\psi_{\dot{\theta}_{sp}}$ and interpreted in terms of the pilot comment data.

6.1 DISCUSSION OF RESULTS FOR GROUP I ($n_z/\alpha \approx 16.5$, $\frac{1}{T_{\theta_2}} \approx 1.29$, $V_T = 411$ ft/sec)

The experimental results for the group I configurations are discussed in this section. The $\dot{\theta}/\delta_e$ transfer function pole locations that correspond to the various short-period frequencies evaluated are shown below along with the average $1/T_{\theta_2}$ zero. The experimental results are presented in Figure 11.



$\dot{\theta}/\delta_e$ TRANSFER FUNCTION POLE LOCATIONS FOR GROUP I

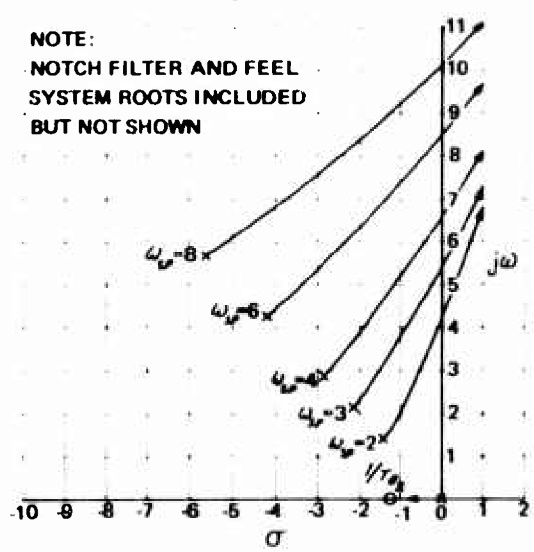
The pilot ratings and pilot comment data for these configurations were quite consistent. The only difference observed between the two pilots' data is that Pilot B's ratings peak at a short-period frequency approximately one half a radian higher than Pilot A's ratings. This is not considered to be a significant difference. Based on the faired curves of the combined pilot rating data, the range of satisfactory short-period frequencies (PR $\leq$ 3.5) is

from 2.4 to 7.0 rad/sec with the best pilot rating occurring at $\omega_{sp} \approx 4.7$ rad/sec. This corresponds to a $T_{\theta_2} \omega_{sp} \approx 3.64$.

The pilot comments indicate that at a short-period frequency of 2 rad/sec the initial response of the airplane is quite sluggish and slow, requiring rather large pilot inputs to start the airplane to respond. However, once the airplane starts to respond there is a strong tendency to overshoot the desired attitude and normal acceleration. The pilots complain that they attempt to drive the airplane to respond quicker than the dynamics will allow and then find that the large initial input must be taken out to avoid the overshooting tendency. The pilots report that they must anticipate the control input required to stop the airplane at a desired attitude. The sluggishness of the initial response, followed by an apparent buildup in pitch rate and normal acceleration, causes the pilot to adopt a technique of: pulsing the control to get the response started, anticipating the final attitude, and pulsing the control in the opposite direction to stop the airplane response.

Another common complaint, for both the fixed and selected F_{EW}/n_z values, is that the initial wheel forces are quite heavy and that they tend to lighten up as the airplane begins to respond. This follows logically from the pilot's description of the airplane response. The compromise here in the selection of a desirable wheel force per g is to get forces that are light enough to get the airplane to respond initially,but heavy enough to prevent the airplane from being overstressed due to the strong tendency to overshoot or overcontrol in pitch rate and n_z. This is a difficult compromise to make.

The third common complaint was that it was difficult to perform a tight tracking task without getting into a low-frequency PIO. The pilots comment that there is no problem if they maneuver relatively slowly and smoothly, but that it was easy to induce a PIO that could only be eliminated at the sacrifice of task performance. The figure below shows a root locus diagram for the θ/δ_e transfer function in which the pilot is considered to be a pure gain



ROOT LOCUS DIAGRAM OF NOMINAL SHORT PERIOD FREQUENCIES, GROUP I

controller closing on attitude with the elevator. It includes the dynamics of the feel system. It can be seen that a relatively low pilot gain is required at the low frequency to produce a low-frequency PIO.

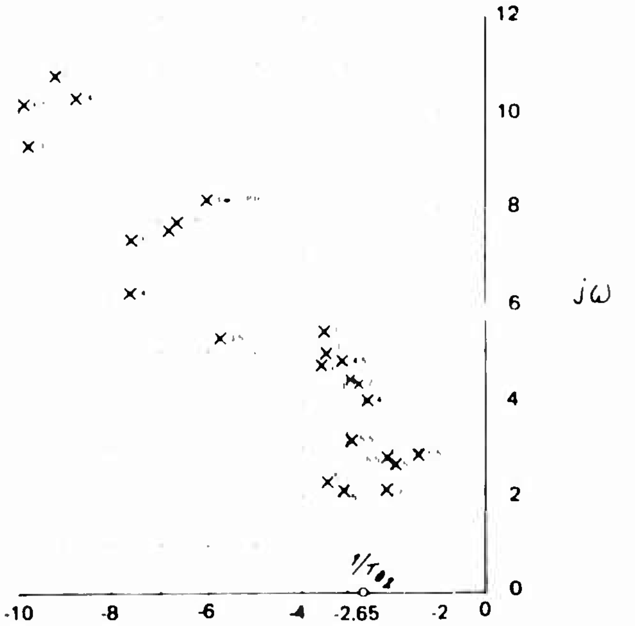
As the short-period frequency is increased to around 4 rad/sec, the initial response is described as quite good, quick but not overly sensitive, and very nice. Both pilots report that the attitude and normal acceleration control are very good. The only complaint is that there is a slight tendency to bobble the airplane for abrupt inputs. Pilot B reports that there was a general tendency to keep his gain up quite high for a tight tracking maneuver and that this resulted in a bobble tendency. Pilot A reported that unless you really tightened up your control there was no tendency to bobble. These statements are certainly compatible and indicate a very nice feeling, responsive, but not overly sensitive airplane, capable of tight precise control. The two configurations given a pilot rating of 7 by Pilot A at this frequency were not downgraded because of the short-period response. The pilot felt that he could inadvertently overstress the airplane because of the light wheel forces. The pilot comments do not justify these unacceptable ratings, therefore these data points have not been considered in the fairing of the pilot rating curves. It should also be pointed out that this same configuration was evaluated at essentially the same F_{EW}/n_z and given a pilot rating of 3.

At 6 rad/sec the configurations were slightly downgraded due to a much stronger tendency to bobble the airplane for tight or precise tracking maneuvers. There was no indication that the initial response was abrupt. There was an attempt by both pilots to divide the response into two parts, as requested on the pilot comment card: an initial and a final response. They both agree that the initial response is quite good, however, there is a tendency to overshoot the desired g and bobble about the steady state value. A brief look at the transient responses in Appendix IV shows the three primary effects of increasing short-period frequency for constant $1/T_{\theta_2}$ and damping ratio. The step input magnitudes were selected to give equal $n_{z_{ss}}$. The initial pitch acceleration or maximum pitch acceleration is increased, the initial pitch rate is increased as well as the pitch rate overshoot. This results in a more rapid pitch angle change initially, followed by the same steady state. If the pilot is closing on attitude, his initial reaction will be to reduce his input because the initial pitch angle change or initial pitch acceleration will be greater than he expected. If he in fact reverses his input, the result would be a tendency to bobble the airplane.

Around 8 rad/sec the initial response is described as being quite fast, a little bit sensitive or fairly fast, and approaching being abrupt. Each configuration was downgraded because of the tendency to "bobble" the airplane when attempting tight attitude or n_z control. This bobbling tendency was especially noticeable for small corrections and led to "longitudinal oscillations" in two cases.

6.2 DISCUSSION OF RESULTS FOR GROUP II ($n_z/\alpha \approx 56.2$, $1/T_{\theta_2} \approx 2.65$, $V_T = 685$ ft/sec)

The experimental results for the Group II configurations are discussed in this section. The $\dot{\theta}/\delta_e$ transfer function pole locations that correspond to the various short-period frequencies evaluated are shown below along with the average $1/T_{\theta_2}$ zero. The experimental results are presented in Figure 12.



$\dot{\theta}/\delta_e$ TRANSFER FUNCTION POLE LOCATIONS FOR GROUP II

The pilot ratings between the two pilots were not as consistent for the Group II configurations as they were for Group I. In general, the faired pilot rating curves show the same trends and peak at the same short-period frequencies, however, Pilot B's pilot ratings are consistently one to one and a half pilot rating numbers higher than those of Pilot A. Based on the faired curves of the combined pilot rating data, the range of satisfactory short-period frequencies (PR $\leq$ 3.5) for Group II is from 5.5 to 12.2 rad/sec, with the best pilot rating occurring at $\omega_{sp} \approx 8.8$ rad/sec. This corresponds to a $T_{\theta_2}\omega_{sp} \approx 3.32$.

At a short-period frequency around 3 rad/sec, both pilots complain that the initial response of the airplane is very sluggish. There is a strong tendency to force the initial response by applying a larger than normal input; then when the airplane does respond, it appears to build up in acceleration much faster than anticipated, resulting in overcontrolling in pitch and normal acceleration. This often resulted in a mild low-frequency PIO. Pilot A reported that the normal acceleration seemed to build up more rapidly than he expected for the amount of pitching motion he was seeing, and that the phasing between the two responses seemed to give him less precise control than he would have liked. It was difficult to maintain tight control of the airplane

due to the sluggish initial response and indefinite final or steady state response. The initial wheel forces seemed quite high, but once the airplane began to react it felt like it wanted to "dig in" with a resulting lightening of the forces.

At 4 rad/sec, Pilot A again commented that the phasing between the normal acceleration and the pitch rate response was less acceptable than just having a low-frequency sluggish airplane. At one point, he commented that it felt as if the normal acceleration was sort of leading the pitch rate, or at least the phasing between the two responses was different than you normally tend to see. The normal acceleration response cannot lead the pitch rate response unless the pilot is sufficiently ahead of the c.g. to feel a significant contribution to n_z from pitch acceleration or the airplane has some form of direct lift control (neither factor was present). The normal accelerations felt by the pilot due to his location with respect to the airplane center of gravity are treated in more detail in Reference 18. The nominal location of the pilot in this experiment was 89.9 inches ahead of the center of gravity. However, it may be possible that the phasing between the n_z and pitch rate responses could be different enough to cause the pilot to comment about their unnaturalness.

Around 6 rad/sec, both pilots liked the responsiveness of the airplane, even though Pilot B commented that the initial response was slightly abrupt. The normal acceleration and pitch attitude control were good with some slight tendency to overshoot or overcontrol for tight tracking tasks. Pilot A again mentions the apparent phasing of the pitch rate and normal acceleration responses. He commented that they seem to be like two different responses. The normal acceleration seems to come on so quickly that you seem to feel the g before you see the attitude change very much. Although the pilot comments that the feeling of separate responses is initially objectionable, he concludes that it sort of helps him in attitude tracking because the g gives him a clue that the airplane is going to move.

As the short-period frequency was increased to 8 rad/sec, Pilot B continued to call the initial response a little abrupt. Although the airplane was fairly responsive, there was very little tendency to overshoot and the pitch attitude and normal acceleration control were considered good by both pilots.

At 10 rad/sec, the initial response is described as quite good and very precise. Pilot A comments that he feels the g coming on very quickly and that he doesn't have to wait for the airplane to rotate very much. He also comments that the g seems to almost lead the pitch rate but that the rate of change of attitude and g onset is quite natural. Both pilots agree that they have excellent pitch attitude and normal acceleration control. The pitch attitude tracking was considered quite good. Pilot B reported a very slight tendency to bobble the airplane for tight tracking maneuvers.

For the highest frequency evaluated of 14 rad/sec, Pilot A describes the initial response as very, very quick but good while Pilot B describes it as somewhat snappy and too abrupt initially. These may seem at first as conflicting observations until one considers the differences in wheel forces selected by the two pilots. The maximum pitch acceleration to a step wheel force input can be described as:

$$\frac{\ddot{\theta}_{MAX}}{F_{EW}} = \frac{\omega_{SP}^2 (\ddot{\theta}_{nd})_{MAX}}{(n_z/\alpha)_{SS} (F_{EW}/n_z)_{SS}} \tag{16}$$

In the two configurations discussed above, Pilot A was operating with an $\left(\frac{F_{EW}}{n_z}\right)_{SS}$ = 49.0 lb/g and Pilot B with an $\left(\frac{F_{EW}}{n_z}\right)_{SS}$ = 32.0 lb/g. It is believed that this large difference in selected F_{EW}/n_z accounts for the difference in the observed initial response characteristics. At the lighter wheel forces selected by Pilot B there was a slight tendency to overshoot during tracking maneuvers that was not observed for the higher wheel forces selected by Pilot A.

6.3 COMPARISON OF RESULTS OBTAINED FOR GROUP I AND GROUP II

A brief review of the two previous subsections shows that for Group I the range of acceptable short-period frequencies (PR $\doteq$ 3.5) is from 2.4 to 7.0 rad/sec with the best pilot rating at $\omega_{sp} \approx$ 4.7 rad/sec. For Group II, the range of acceptable short-period frequencies (PR $\doteq$ 3.5) is from 5.5 to 12.2 rad/sec with the best pilot rating occurring at $\omega_{sp} \approx$ 8.8 rad/sec.

The pilot comments for the configurations corresponding to the short-period frequencies above and below the optimum frequency for each group are nearly identical. At the lower than acceptable short-period frequencies, the pilots complain about the extreme slowness and sluggishness of the initial response which makes the pilot attempt to force the airplane to respond by putting in a large pulse type input. This results in a more rapid buildup in pitch rate and normal acceleration than anticipated, leading to overcontrolling and mild, low-frequency PIO tendencies. At the higher than acceptable short-period frequencies, the major complaint is the sensitivity or abruptness of the initial response and the strong tendency to "bobble" the airplane during a tight tracking task.

The pilots find that they must accept a compromise in their selection of a desirable wheel force per g at both extremes of short-period frequencies. For the lower frequencies there is a desire to have light wheel forces initially to get the airplane to respond; however, the light wheel forces result in over-controlling and overstressing (g-limiting) problems which heavier wheel forces improve. Thus the selected F_{EW}/n_z is a compromise. At the higher frequencies, the reverse is true. The initial response is sensitive or abrupt presenting a requirement for heavier wheel forces initially, but then the steady state maneuvering forces become excessive; thus, another compromise.

At the best short-period frequencies for the respective groups evaluated, the pilots describe the initial response as quite good in both cases, as quick but not overly sensitive. In general the pilot can keep his gain up quite high, accept lower wheel forces per g, and not "bobble" the airplane during tight tracking tasks. These configurations are called precise with very good attitude and normal acceleration control.

It is clear that the short-period frequency requirements are quite different for the two groups of configurations evaluated. It is also clear that the acceptable band of short-period frequencies becomes wider as the value of $1/T_{\theta_2}$ or n_z/α is increased and that this band is shifted in the direction of higher frequencies. The next logical questions are: why does this occur? Is there a common relationship that allows the desired variation in short-period frequency requirements to be determined at other values of n_z/α, $1/T_{\theta_2}$ and V_T ?

The concepts which lead to the control anticipation parameter (CAP) developed in Reference 12, and extended to include the attenuating effects of the feel system (CAP') in Reference 2[2], seem to provide a good explanation of the closed-loop difficulties the pilot experiences, in particular, with regard to the initial responses. The CAP theory is based on the premise that the pilot must be able to anticipate the final response of the airplane, and that this anticipation signal is provided through the pitching acceleration of the airplane to a pilot input. Thus at the lower than optimum short-period frequencies, the sluggish or slow initial response does not provide the pilot with the desired anticipatory cue that he expects. This causes him to increase his input to the extent that when the airplane does respond, a large change in pitch rate and normal acceleration results with a corresponding overcontrol or overshooting tendency. This same cue is missing when the pilot attempts to stop the airplane response and, as indicated in Reference 12, can result in a PIO.

At the higher than acceptable short-period frequencies, the CAP theory explains that the pilot experiences such a large pitch acceleration, and therefore a very high level of anticipatory cue, for the small steady state flight path correction desired, he will immediately limit or partially retract some of his control input. This action will result in a smaller flight path correction than desired and the pilot, in repeating the same sequence of inputs, will bobble the airplane or possibly enter a PIO.

Figures 13, 14, and 15 show the variation of pilot rating as a function of CAP. It can be seen that there is very good agreement between pilots. The faired pilot rating curve shows a range of acceptable CAP values from .43 to 2.4 rad/sec^2. The lower boundary correlates quite well with the lower acceptable limit of .436 rad/sec^2 established in Reference 12 which does not give an upper limit. It should be pointed out here that the parameters that make up CAP are

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$$CAP = \frac{\omega_{sp}^2}{(n_z/\alpha)_{ss}}, \quad CAP' = \frac{\omega_{sp}^2 (\ddot{\theta}_{nd})_{MAX}}{(n_z/\alpha)_{ss}}$$

only airframe open-loop parameters and, as indicated in Reference 2, may not necessarily describe the actual pitch acceleration response of the airplane because of the attenuating effects of the feel system.

It is generally accepted that the pilot flies the airplane by force inputs rather than position inputs and that the parameter F_{EW}/n_z is quite important to the overall longitudinal handling qualities. In view of the importance given to the initial pitch acceleration by the CAP theory, it is worthwhile to consider the attenuating effects of the feel system and the effects of variations in F_{EW}/n_z on this parameter. As shown in Section V for satisfactory short-period damping ($\zeta_{sp} \approx .7$), the maximum pitch acceleration to a step force input can be written:

$$\frac{\ddot{\theta}_{MAX}}{F_{EW}} = \frac{\omega_{SP}^{2}\left(\ddot{\theta}_{nd}\right)_{MAX}}{\left(\frac{n_z}{\alpha}\right)_{SS}\left(\frac{F_{EW}}{n_z}\right)_{SS}} \tag{17}$$

where $(\ddot{\theta}_{nd})_{MAX}$ accounts for the attenuation of the feel system on the maximum pitch acceleration to a step input and $(n_z/\alpha)_{SS}$ and $(F_{EW}/n_z)_{SS}$ are steady state parameters which are not affected by the feel system. Since this parameter contains two of the quantities considered to be important in longitudinal handling qualities, it should possibly give a better indication of the closed-loop handling qualities than just the open-loop parameters of CAP. Thus Figures 16 and 17 show the variation of pilot rating as a function of $\ddot{\theta}_{MAX}/F_{EW}$. In general there is not very good correlation between pilot rating and $\ddot{\theta}_{MAX}/F_{EW}$. This is especially true between the two groups. The ratings of the two pilots are quite compatible for a given group, but there seems to be no common relationship existing between the ratings for the different groups.

This is primarily due to the large attenuation of the feel system on the maximum pitch acceleration to a step input at the high short-period frequencies. Much better correlation between the groups of data is obtained when the attenuating effects of the feel system are neglected, as can be seen in Figures 13, 14, and 15 which show pilot rating versus $\ddot{\theta}/F_{EW}$. In general, correlation is good at the lower than optimum short-period frequencies but not very good at the higher frequencies. This is primarily due to the trends exhibited by the two pilots in their selections of F_{EW}/n_z. This is discussed in greater detail in Section 6.5. Briefly, Pilot A tended to follow the basic pattern established in Reference 2 for the selection of F_{EW}/n_z as a function of short-period frequency and n_z/α, while Pilot B tended to select lower wheel forces as the short-period frequency increased at both n_z/α's. Thus Pilot B experienced higher values of $\ddot{\theta}/F_{EW}$ than Pilot A. This is confirmed by the pilot comment data which indicates that Pilot B felt the higher frequency configurations were more abrupt in the initial response than Pilot A.

Although the importance of the pitch acceleration is well established, there are indications that pitch acceleration does not tell the entire story and therefore is not necessarily the only variable the pilot is attempting to optimize. The selection of F_{EW}/n_z, at the higher and lower than acceptable short-period frequencies, for the two groups evaluated, was a compromise based on both the initial pitch acceleration and the steady state forces required to maneuver the airplane. Briefly, at the lower short-period frequencies, the pilot would like to have light wheel forces to get the airplane to respond initially but he overcontrols in the steady state if the forces are light. At the higher short-period frequencies, the pilot would like to have heavy wheel forces to reduce the abruptness of the initial response but he objects to the resulting heavy steady state forces. Thus the compromise the pilot must make in the selection of a desirable F_{EW}/n_z is not based solely on the initial response or initial pitch acceleration but also on the steady state maneuvering forces.

If we assume the pilots can consistently optimize the F_{EW}/n_z for a given short-period frequency, even though serious compromise's are required, we should be able to look at $\frac{\ddot{\theta}_{MAX}}{(n_z)_{ss}}$ which includes the attenuation of the feel system but does not include the effects of F_{EW}/n_z. This yields the parameter (CAP') developed in Reference 2 and is defined as:

$$CAP' = \frac{\ddot{\theta}_{MAX}}{(n_z)_{ss}} = \frac{\omega_{SP}^2 (\ddot{\theta}_{nd})_{MAX}}{(n_z/\alpha)_{ss}} \tag{18}$$

This parameter is simply the control anticipation parameter developed in Reference 12, but with the attenuating effects of the feel system included. If the pilot used only step inputs, then CAP' would probably be more representative of the actual pitch accelerations felt by the pilot following a control input. Figures 21, 22, and 23 show the variation of pilot rating as a function of CAP'. Once again we see good correlation between pilots for each of the groups, but very poor correlation of the pilot ratings between the two groups. This is especially true at the higher frequencies where the attenuation of the feel system is most noticeable. It appears that there is an upper limit of CAP' for both of the groups. For Group I there is an upper limit of CAP' = 1.25 while Group II has an upper limit of CAP' = .77.

Both the CAP and CAP' developments place unwarranted emphasis on the initial pitch acceleration response to an ideal step input. Although pilots may use abrupt control inputs to initiate maneuvers, they do not normally use sharp or ideal step inputs to fly the airplane. The pilot comments in this experiment indicate the importance of both the initial and the steady state responses to control inputs. The initial response has meaning to the pilot when abruptly initiating maneuvers and also in tracking type inputs where no steady state is established. The steady state response has meaning during steady maneuvers such as pullups and steady turns. It is worthwhile then to look at the magnitude and phase relationships that exist between the airplane responses and an elevator wheel force input. These relationships are illustrated in Figure 24 where the asymptotic Bode plots for the longitudinal

airplane responses are shown. From these plots, we can see that the $\ddot{\theta}$ gain at the frequencies where the pitch acceleration is in phase with the wheel force input is essentially $M_{F_{EW}}$. The n_z gain at the frequencies where n_z is in phase with the wheel force input is $\frac{VM_{F_{EW}}}{g\, T_{\theta_2}\, \omega_{sp}^2}$. Note that the first of these two statements applies only when the feel system and control system frequencies are widely separated from the short-period frequency. This condition did exist in this experiment. Reference 16 presents an investigation of the effects when this is not the case. If we take the ratio of these two gains as being representative of the two important response characteristics discussed above, we have:

$$\frac{\left|\frac{\ddot{\theta}}{F_{EW}}\right|_{\substack{\text{at frequency}\\\text{where phase}\\\text{is zero}}}}{\left|\frac{n_z}{F_{EW}}\right|_{ss}} = \frac{M_{F_{EW}}}{\frac{V}{g}\,\frac{M_{F_{EW}}}{T_{\theta_2}\,\omega_{sp}^2}} = \frac{\omega_{sp}^2}{\frac{V}{g}\,\frac{1}{T_{\theta_2}}} = \frac{\omega_{sp}^2}{n_z/\alpha}$$

This is recognized as the CAP parameter developed in Reference 12, however, the expression has been developed without the dependence on an elevator wheel step input assumed in Reference 12. The reasoning behind the above development seems to be more compatible with the pilot comments. This is especially true concerning the comments that result from the pilot's selection of the control gain. These comments emphasize the importance of both the initial and final responses and make the point that the sensitivity of importance and the steady control gain of importance may involve different responses and even separate maneuvers or tasks.

Reference 6 concluded from a ground simulator program that for values of n_z/α greater than ten, pilots desire to have precise control of normal acceleration. This is further modified by Reference 9 to a value of n_z/α greater than fifteen before the pilot changes his reference of control from pitch attitude to normal acceleration. Since this program was conducted at n_z/α's of 16.5 and 56.2, it is worthwhile to consider how pilot ratings vary with normal acceleration characteristics. Reference 9 suggests the use of $(n_z/\alpha)/\omega_{sp}$ as a parameter that should reflect airplane normal acceleration characteristics at n_z/α's greater than 15. Figures 25 and 26 show how the pilot ratings varied as a function of $(n_z/\alpha)/\omega_{sp}$. There is excellent agreement between pilots within a group but very poor correlation between groups.

So far it has been shown that those parameters which attempt to include the attenuation effects of the feel system to a step input or wheel force per g have given poor correlation between pilot ratings obtained for the two groups of configurations. It has also been shown that pilot rating versus $(n_z/\alpha)/\omega_{sp}$ has not correlated very well at different values of n_z/α. The best correlation has been obtained for the parameter $\omega_{sp}^2/(n_z/\alpha)$. This is the parameter chosen to establish short-period frequency requirements in Reference 1.

The major objective of this program was to investigate the short-period frequency requirements for a low to medium load factor wheel controlled airplane at a high range of n_z/α for comparison with the requirements proposed in Reference 1. Figure 27 shows the pilot rating data obtained during this experiment plotted on the proposed MIL-F-8785 specification requirements. Within the level 1, Flight Phase Category A boundary, the airplane must have a pilot rating of 3.5 or less and within the level 2, Flight Phase Category A boundary, a pilot rating of 6.5 or less, for the task of precision maneuvering. The faired pilot rating data of this experiment possibly indicates that the upper limit on ω_{sp} as a function of n_z/α is a little high, and that the lower limit might converge slightly toward the upper limit at the high n_z/α.

The technical discussion presented earlier suggests that perhaps the best short-period frequency, at a given ζ_{sp}, will be the one that gives the pilot the best combination of $\dot{\theta}$ and n_z responses. The author does not necessarily hold with the conclusion that, at high speed or high n_z/α, the pilot is attempting to control n_z precisely at the expense of the pitch attitude response. In the steady state, the pitch rate and normal acceleration responses are directly related by the velocity $\left[(n_z)_{ss} = \frac{V}{g}(\dot{\theta}_{ss})\right]$. At high speed, and therefore high n_z/α, the pilot reaches the acceleration limits of the airplane long before he reaches a value of $\dot{\theta}$ that might be objectionable. This means that n_z, though certainly more important at high speed than at low speed, is not normally controlled tightly unless the pilot is near the n_z limits of the airplane. Experience tends to bear out that the pilot will rotate the airplane from target to target at the maximum n_z consistent with pilot and structural limitations in order to minimize acquisition time; however, when structural limitations are not paramount, the pilot will close on pitch attitude in order to track. Since $\dot{\theta}$ and n_z are both important, a reasonable approach, consistent with the piloting task, is to observe the $\dot{\theta}$ response while normalizing the n_z response. Since the pilot does close on attitude, the $\dot{\theta}$ response maintains its importance at high n_z/α and therefore could possibly be used to correlate longitudinal handling qualities at high as well as low speeds. Figure 28 shows the actual pole locations for the θ/δ_e transfer function that were used during the evaluation program. It can be seen in Figure 28 that the best short-period frequency, as determined from the faired pilot rating curves for both groups, occurs at approximately the same phase angle with respect to the zero determined by the $1/T_{\theta_2}$ of the configuration. Since this angle is a function only of ω_{sp}, ζ_{sp} and $1/T_{\theta_2}$ this means that in this experiment the best short-period frequency, for the two groups evaluated, occurred at essentially the same value of $T_{\theta_2}\omega_{sp}$. Therefore it was worthwhile to plot pilot rating as a function of $T_{\theta_2}\omega_{sp}$.

This approach is not new as it is suggested in Reference 9 for values of n_z/α less than 15 g/rad. However, here it is extended to much larger values of n_z/α and the parameter $T_{\theta_2}\omega_{sp}$ is used in place of $\frac{1}{T_{\theta_2}\omega_{sp}}$[3] as suggested in Reference 9, because the significance of $\frac{1}{\omega_{sp}}$ is not as clearly understood as a variation in ω_{sp}. It is also better to correlate with a parameter that increases with increasing ω_{sp} and does not "blow up" as ω_{sp} approaches zero.

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[3] $\frac{1}{T_{\theta_2}} \approx L_\alpha$ when $L_{\delta_e} \approx 0$.

Figures 29, 30 and 31 show the variation of pilot rating with a change in $T_{\theta_2} \omega_{sp}$. It can be seen that there is excellent agreement between pilots for each group of data, as well as very good agreement between groups. The faired pilot rating curves, for both pilots for both groups of data, show that the best pilot ratings occur at $T_{\theta_2} \omega_{sp} \approx 3.6$. It also shows that acceptable short-period handling qualities (PR $\leq$ 3.5) occur for a range of $T_{\theta_2} \omega_{sp}$ between 2.2 and 5.3.

By maintaining a constant value of $T_{\theta_2} \omega_{sp}$ at a constant damping ratio, the shapes of the longitudinal responses to a step input are preserved. This also means that the pitch rate overshoot ($\dot{\theta}_{MAX}/\dot{\theta}_{SS}$) and the phasing of the $\dot{\theta}$ response with respect to the α and n_z responses is held constant.

From the two equations developed in Appendix I and shown below,

$$\frac{\dot{\theta}_{MAX}}{\dot{\theta}_{ss}} = 1 - \frac{1}{\sqrt{1-\zeta_{sp}^2}} \sqrt{\left(T_{\theta_2}\omega_{sp}\right)^2 - 2\zeta_{sp}\left(T_{\theta_2}\omega_{sp}\right) + 1}\; e^{\frac{\zeta_{sp}}{\sqrt{1-\zeta_{sp}^2}} \tan^{-1}\left[\frac{\sqrt{1-\zeta_{sp}^2}}{\frac{1}{T_{\theta_2}\omega_{sp}} - \zeta_{sp}}\right]} \sin\left[\tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^2}}{\zeta_{sp}}\right)\right] \quad (19)$$

and

$$\psi_{\dot{\theta}_{sp}} = \tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^2}}{\frac{1}{T_{\theta_2}\omega_{sp}} - \zeta_{sp}}\right) + \tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^2}}{\zeta_{sp}}\right) \quad (20)$$

having a constant value of $T_{\theta_2} \omega_{sp}$ and ζ_{sp} will maintain a constant pitch rate overshoot, $\left(\frac{\dot{\theta}_{MAX}}{\dot{\theta}_{MAX}}\right)$, and as shown in Section II, will keep the same phasing between the $\dot{\theta}$, α and n_z responses. In this experiment, the optimum short-period frequency occurred at a value of $T_{\theta_2} \omega_{sp} \approx 3.6$ with a range of $2.2 \leq T_{\theta_2} \omega_{sp} \leq 5.3$ for acceptable short-period handling qualities (PR $\leq$ 3.5).

From Figure 28 and Equation 21, it can be seen that a constant value of $T_{\theta_2} \omega_{sp}$ (at a constant damping ratio) results in a constant phase angle for the $\dot{\theta}$ response to a step input. As pointed out in Section II, one of the effects of changing the value of T_{θ_2} is to change the phase relationship of the $\dot{\theta}$ response with respect to the α and n_z responses. If there is, in fact, a desirable phase relationship between the $\dot{\theta}$ and n_z responses, then it should be possible to correlate pilot rating with $\psi_{\dot{\theta}_{sp}}$. Figures 32, 33 and 34 show how pilot rating varied as a function of the phase angle of the $\dot{\theta}$ step response at the short-period frequency. Although the damping was not varied in this experiment, these phase angles include the actual measured damping ratios obtained for each configuration. Although there is good correlation at the phase angles less than the optimum, there is very poor correlation for those phase angles greater than the optimum. This is primarily the result of the small change in $\psi_{\dot{\theta}_{sp}}$ that occurs for even a large change in ω_{sp} at values of $\psi_{\dot{\theta}_{sp}}$ greater than optimum. The evidence of poor correlation lies in the large changes that occur in pilot rating for very little change in $\psi_{\dot{\theta}_{sp}}$ at the high phase angles.

Since it has been shown that the pilot rating data correlates as well with $T_{\theta_2}\,\omega_{sp}$ as it does with $\frac{\omega_{sp}^2}{n_z/\alpha}$, it is reasonable to ask which of these parameters is the more correct correlating parameter? n_z/α is approximately equal to $(\frac{V}{g})\,1/T_{\theta_2}$ and thus $\frac{\omega_{sp}^2}{n_z/\alpha} \approx \frac{g}{V}(\omega_{sp})(T_{\theta_2}\,\omega_{sp})$. Unfortunately, the only conclusion that can be reached from this experiment is that the optimum short-period frequency was different for the two groups evaluated. Whether this variation was due to the independent effect of V or $1/T_{\theta_2}$, or a combination of both, cannot be ascertained. There is, however, a ground simulator experiment, Reference 6, that shows that pilot rating varies as a function of velocity at a constant L_α. Based on these ground simulator results, it would seem that $\frac{\omega_{sp}^2}{n_z/\alpha}$ is the better of the two correlating parameters. Since $\frac{\omega_{sp}^2}{n_z/\alpha}$ contains $T_{\theta_2}\,\omega_{sp}$ and $\frac{\omega_{sp}}{V}$, if there are variations in pilot rating due to the independent effects of velocity, they can be accounted for by $\frac{\omega_{sp}^2}{n_z/\alpha}$ whereas they cannot by $T_{\theta_2}\,\omega_{sp}$ alone. Neither $T_{\theta_2}\,\omega_{sp}$ nor $\frac{\omega_{sp}^2}{n_z/\alpha}$ contain the effects that variations in short-period damping impose. Thus we must conclude that any parameter that contains only two of the three variables ω_{sp}, ζ_{sp} and $1/T_{\theta_2}$, has no chance of covering all possible cases.

The primary objective of this investigation was to ascertain the desirable values of short-period frequency at high n_z/α for wheel-controlled airplanes with low to medium limit load factors. A second objective was to compare the results obtained in this program using a wheel controller to those obtained in Reference 2 with a stick controller. Although a comparison can be made, it should be pointed out that the mission requirements for the two programs were quite different. The pilots in Reference 2 evaluated an airplane for the fighter mission and the pilots in this program evaluated a task representative of a much larger, less maneuverable airplane with a wheel controller. Figure 35 presents the pilot rating data versus short-period frequency from Reference 2 plotted on the corresponding data from this experiment. The most significant result is that the short-period frequency requirements for a wheel-controlled airplane are identical to those of an airplane with a stick controller. This is an important conclusion because it allows direct comparison of short-period frequency data obtained in airplanes with either type of controller. Although the short-period frequency requirements are the same, one major difference in the pilot rating data was evident. For the Group I configurations, in the lower than acceptable short-period frequency range, the pilot ratings for the stick-controlled fighter airplane dropped off quite a bit more rapidly than those for the medium load factor wheel-controlled airplane. This same trend was not as evident for the Group II configurations. The dropoff in pilot rating is primarily attributed to the mission requirements where the desire for increased maneuverability in the fighter is greatly impaired by the slow initial response characteristics exhibited in this short-period frequency range.

6.4 DISCUSSION OF RESULTS OF PIO INVESTIGATION

Pilot A made a brief evaluation of four Group I and three Group II configurations for which the short-period damping ratio was reduced from a nominal value of $\zeta_{sp} \approx 0.7$ to a value of $\zeta_{sp} \approx 0.1$. All but one of these configurations were evaluated twice; once for a fixed F_{EW}/n_z and a second time with the opportunity for the evaluation pilot to select a desired value of F_{EW}/n_z. Table IV-III lists the configurations evaluated.

For Group I with fixed F_{EW}/n_z values, each of the configurations except the one at 6.09 rad/sec was rated as unacceptable because of a tendency to overstress the airplane due to light wheel forces rather than because of PIO tendencies. When the F_{EW}/n_z was increased, the pilot ratings became better. This does not mean that the pilot did not experience PIO tendencies, because the pilot comments indicate that these problems did exist. For both the 1.96 rad/sec and 4 rad/sec configurations, the pilot indicated that when he attempted to tighten his control loop, he found that the oscillations just got larger. Increasing F_{EW}/n_z reduced these oscillations. At 6.09 rad/sec, the pilot experienced similar oscillations which were considered objectionable, but his major complaint was the reaction of the airplane to the random noise disturbance inputs.

The low frequency configuration evaluated in Group II had such a heavy F_{EW}/n_z that the airplane was extremely difficult to maneuver. The configuration was considered to have a bobbling tendency but this was completely overshadowed by the heavy wheel forces. At 6.0 rad/sec the pilot indicated that he could track fairly well at low gain in smooth air. The major complaint for this configuration, as in the Group I case, was that the control in the presence of the random elevator disturbances made the airplane unacceptable. The same comments were found for the configuration evaluated at 10.3 rad/sec. There was a greater tendency to bobble the airplane when attempting to track in smooth air than at 6 rad/sec, but the characteristic that made the configuration unacceptable was again the performance in the presence of the random noise disturbance.

Intuitively it would seem reasonable that a high-frequency airplane would be more susceptible in pitch to external disturbances, especially at the low damping ratio ($\zeta_{sp} \approx .1$) evaluated. This suggests that there is possibly an upper boundary to the short-period frequency for light short-period damping ratios due to the airplane pitch response to external disturbances. This seems to be the case here; unfortunately there are very few data points and the random noise disturbance does not realistically simulate natural turbulence, i.e., the elevator input applies only pitching moments and does not simulate the heaving motion normally found in natural turbulence.

It can also be concluded that PIO problems did exist for most of the configurations. It was also possible to reduce the consequences of these oscillations by increasing the wheel forces. For this experiment, it can be said that for short-period frequencies of 6 rad/sec and greater, and at a damping ratio of $\zeta_{sp} \approx .1$, the major complaint of the pilot was the response of the airplane to the random noise inputs through the elevator and that this occurred for both the high and low n_z/α cases.

6.5 COMPARISON OF RESULTS OF SELECTED $\frac{F_{EW}}{n_z}$ VALUES

Each of the configurations was evaluated at least twice, once with a fixed F_{EW}/n_z determined to lie within the proposed F_{EW}/n_z requirements established in Reference 1 and varied as a function of ω_{sp} according to the results of the experiemnt conducted in Reference 2, and again with the opportunity for the pilot to select what he considered to be an optimum F_{EW}/n_z.

Figures 36 and 37 show a comparison of the values of F_{EW}/n_z as a function of short-period frequency at a given value of n_z/α between those fixed during the evaluation and those selected by the evaluation pilot.

The F_{EW}/n_z values selected by Pilot A show the same trend as those fixed in the experiment, however, they are generally 5 to 10 pounds heavier than the fixed values. The two obviously heavy F_{EW}/n_z values selected by Pilot A at 3.6 and 4.2 rad/sec for Group I were felt necessary to give structural protection in a symmetrical pullup, but admittedly resulted in forces that were a little high in a steady g turn. It is interesting that he evaluated this same configuration two other times at an $F_{EW}/n_z \approx 40$ lb/g and rated it as acceptable satisfactory once and as unacceptable the other time. The unacceptable rating was due to the pilot's concern about overstressing the airplane because of the light F_{EW}/n_z. It is the author's opinion that the pilot comments do not justify an unacceptable rating, particularly when they are compared with the comments for the same configuration at essentially the same F_{EW}/n_z value evaluated earlier.

The F_{EW}/n_z values selected by Pilot B do not show the same trend as those fixed in the experiment; as the short-period frequency increased, the selected values of F_{EW}/n_z continued to decrease. The result was that Pilot B had more complaints about the initial response being sensitive or abrupt at the higher short-period frequencies. The low value of F_{EW}/n_z selected at 5.3 rad/sec for Group II was admitted by the pilot to be too light.

A comparison of the pilot ratings as a function of short-period frequency and F_{EW}/n_z is shown in Figures 37 and 38 for the levels and flight phase categories presented in Reference 1. Essentially, the airplane must have a pilot rating of 3.5 or less within the Level 1, Flight Phase Category A boundary and a pilot rating of 6.5 or less within the Level 2, Flight Phase Category A boundary for the task of precision maneuvering. It can be seen that in general, these criteria have been met with the exception of a few discrete points.

The wheel force requirements in this experiment were quite different from the stick force requirements established in Reference 2. It is difficult to make a direct comparison because of the significantly different limiting load factors and the different mission requirements for the two experiments. There was a stronger tendency to use the control force level to provide structural protection for the wheel-controlled airplane than for the stick-controlled fighter. This could indicate that control force per g is more important for structural protection in a low to medium load factor airplane than in a high load factor airplane where the human tolerance to normal acceleration becomes

the more important consideration. In other words, for low n_z structural limits, the pilot's perception of the limiting g is not very good in comparison with the case of a high n_z structural limit where considerable pilot discomfort and physiological changes may occur. Thus the higher wheel forces accomplish two things: they provide the pilot with an increased degree of n_z perception and physically make the airplane more difficult to overstress.

6.6 DISCUSSION OF RESULTS OF THE $\frac{\delta_{EW}}{n_z}$ STUDY

One flight during the in-flight evaluation program was used to evaluate the effect on the short-period handling qualities of variations in δ_{EW}/n_z. The configuration used was a Group I configuration that had been rated acceptable satisfactory with a $\delta_{EW}/n_z \approx 1$ in./g. Additional values of δ_{EW}/n_z equal to 2, 3, and 4 in./g were evaluated while holding F_{EW}/n_z essentially constant. The configurations were evaluated by Pilot B.

The original configuration was evaluated three times at a $\delta_{EW}/n_z \approx 1$ in./g and given ratings of 1.5, 2.0 and 2.0. The wheel displacements were described as comfortable in the first evaluation and moderate in the last two. The configuration, in general, was quite good with good tracking capability

With δ_{EW}/n_z increased to 2.05 in./g, the wheel displacements were described as a "little on the high side." The increased displacements were slightly more noticeable and caused the pilot to comment: "there was something about the feel of the aircraft that made it difficult for me to tell whether the stick displacements were large or whether the response was just slow." The pilot, though commenting about the wheel displacements, seemed to feel his difficulty in a tight tracking maneuver was due mostly to the airplane dynamics. The configuration was given a pilot rating of 3.

At a δ_{EW}/n_z= 3.3 in./g, the increased wheel displacements were quite noticeable, described as "rather large," and were listed as an objectionable feature. The pilot found it was often easy to get out of phase with the tracking needle during the random error tracking task and commented that he could not do any very tight tracking. The configuration was given a pilot rating of 4.

For the highest δ_{EW}/n_z evaluated of 3.94 in./g, the pilot reported that it seemed to take a lot of wheel input to get any amount of initial response and that the wheel displacements seemed quite large. Once again the pilot reported that his tracking was poor. The pilot listed as an objectionable feature that the control inputs had to be large to get anything out of the airplane and he rated the airplane a 5.

Figure 39 shows the variation in pilot rating as a function of δ_{EW}/n_z. The pilot ratings deteriorate with increasing δ_{EW}/n_z and indicate that the handling qualities were less than acceptable satisfactory for values of δ_{EW}/n_z greater than about 2.5 in./g. Figure 40 shows the comparison of the pilot ratings obtained at the various values of δ_{EW}/n_z with the proposed levels established in Reference 1.

SECTION VII
CONCLUSIONS

A flight test program was conducted to investigate the short-period handling qualities requirements at a constant damping ratio ($\zeta_{SP} \approx .7$) at two flight conditions for a wheel-controlled airplane with a low to medium load factor. The two flight conditions consisted of two velocities at a constant altitude. This resulted in two values of $1/T_{\theta_2} \approx L_\alpha$ and two true speeds. The following conclusions were reached:

1. The short-period frequency requirements were different for the two flight conditions. As $1/T_{\theta_2}$ and velocity were increased, the band of acceptable short-period frequencies was widened and shifted in the direction of higher frequencies.

2. Pilot opinion of the longitudinal short-period handling qualities was found to deteriorate for frequencies above and below an optimum frequency, for essentially the same reasons at both flight conditions. For those frequencies below the optimum, the pilots complained about the sluggishness of the initial response and the tendency to overcontrol and possibly enter a low-frequency PIO. At the higher than optimum frequencies, the pilots complained about the abruptness or sensitivity of the initial response and the tendency to bobble the airplane.

3. Selection of an optimum F_{EW}/n_z is a compromise between desirable initial response and acceptable steady state forces for those frequencies above and below the optimum. At the lower than optimum short-period frequencies, the pilot wishes to have light wheel forces to make the airplane respond initially but this leads to overcontrol and overstressing tendencies. For the higher than optimum short-period frequencies, the pilot would like heavy wheel forces to reduce the abruptness of the initial response, but then he finds the steady state forces excessive.

4. Pilot rating data was shown to correlate with two parameters: $\omega_{SP}^2/(n_z/\alpha)$ and $\omega_{SP}\,T_{\theta_2}$. The following limits were established for acceptable satisfactory pilot ratings (PR $\leq$ 3.5): $(.43 \leq \omega_{SP}^2/(n_z/\alpha) \leq 2.4)$ and $(2.2 \leq T_{\theta_2}\,\omega_{SP} \leq 5.3)$.

5. For the constant damping ratio cases investigated, the optimum short-period frequency occurred at the same phase angle of the short-period mode in the $\dot{\theta}$ time history response to a step elevator input.

6. The short-period frequency requirements for a low to medium load factor airplane with a wheel controller are nearly identical with those for a fighter type airplane with a stick controller. The only significant difference is that the pilots are more tolerant of lower than optimum short-period frequencies for the mission of the wheel-controlled airplane than they are for the same conditions for the fighter mission. This is an important conclusion because it allows direct comparison of short-period frequency data obtained with either wheel- or stick-controlled airplanes.

7. Pilot opinion of longitudinal handling qualities is significantly influenced by the amount of wheel motion required to pull an incremental normal acceleration. It was shown that a $\delta_w/n_z \approx 2.5$ in./g or greater resulted in unsatisfactory handling qualities.

8. Reducing the short-period damping ratio to $\zeta_{sp} \approx .1$ greatly increased the tendency toward pilot-induced oscillations. For this experiment, it was found that for short-period frequencies of 6 rad/sec or greater at a damping ratio of $\zeta_{sp} \approx .1$, the major cause for the unacceptable pilot ratings was the response of the airplane to the random noise disturbances to the elevator.

	ω_{SP}	ζ_{SP}	$1/T_{\theta_2}$	V
———	4 RAD/SEC	0.7	1.6 SEC^{-1}	322 FT/SEC
xxxxxxxx	4 RAD/SEC	0.7	3.2 SEC^{-1}	322 FT/SEC

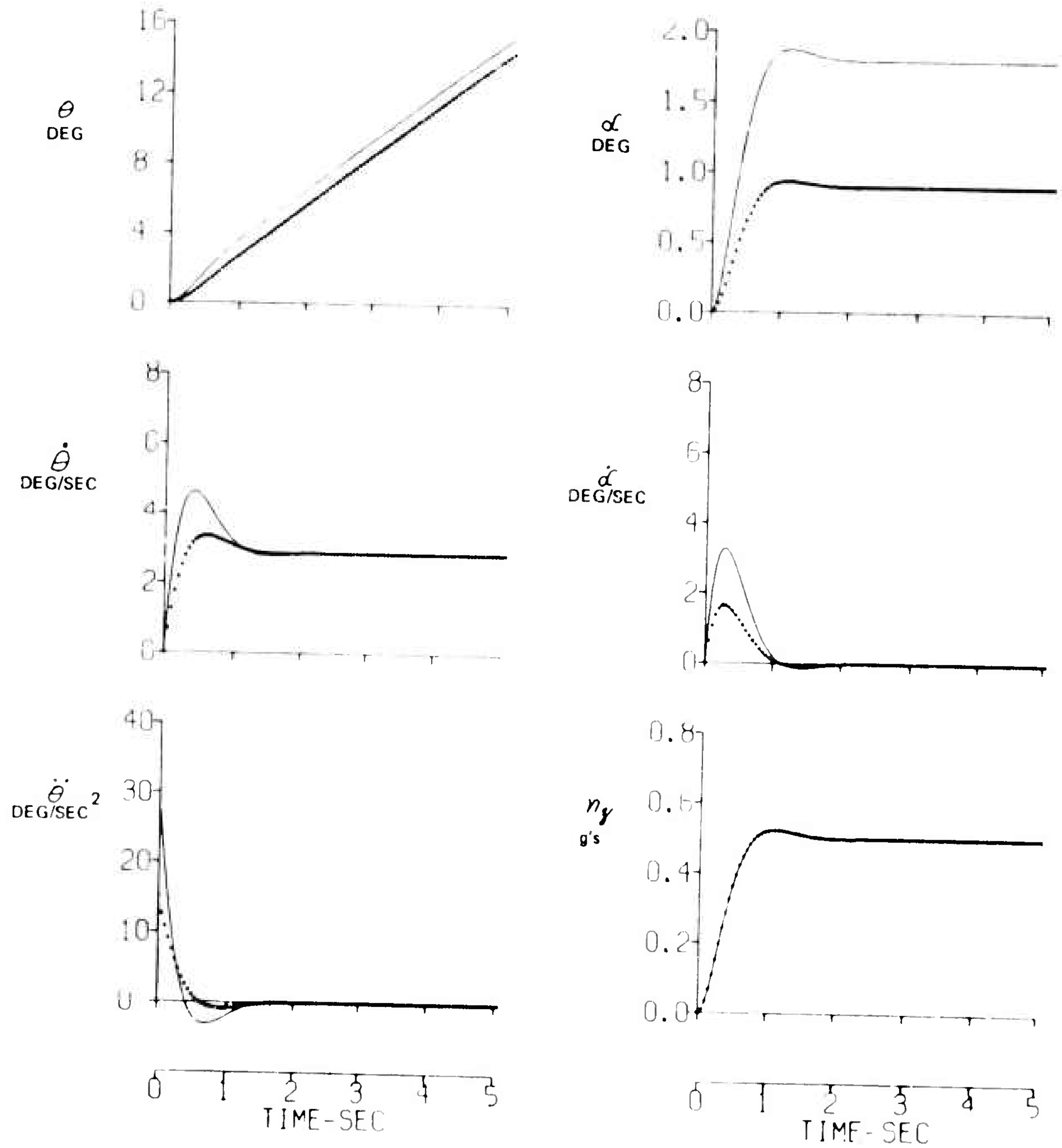


Figure 1 EFFECT OF VARYING $1/T_{\theta_2}$ ON RESPONSE TO ELEVATOR STEP INPUT

	ω_{SP}	ζ_{SP}	$1/T_{\theta_2}$	V
————	4 RAD/SEC	0.7	1.6 SEC^{-1}	322 FT/SEC
xxxxxxxxxx	4 RAD/SEC	0.7	1.6 SEC^{-1}	644 FT/SEC

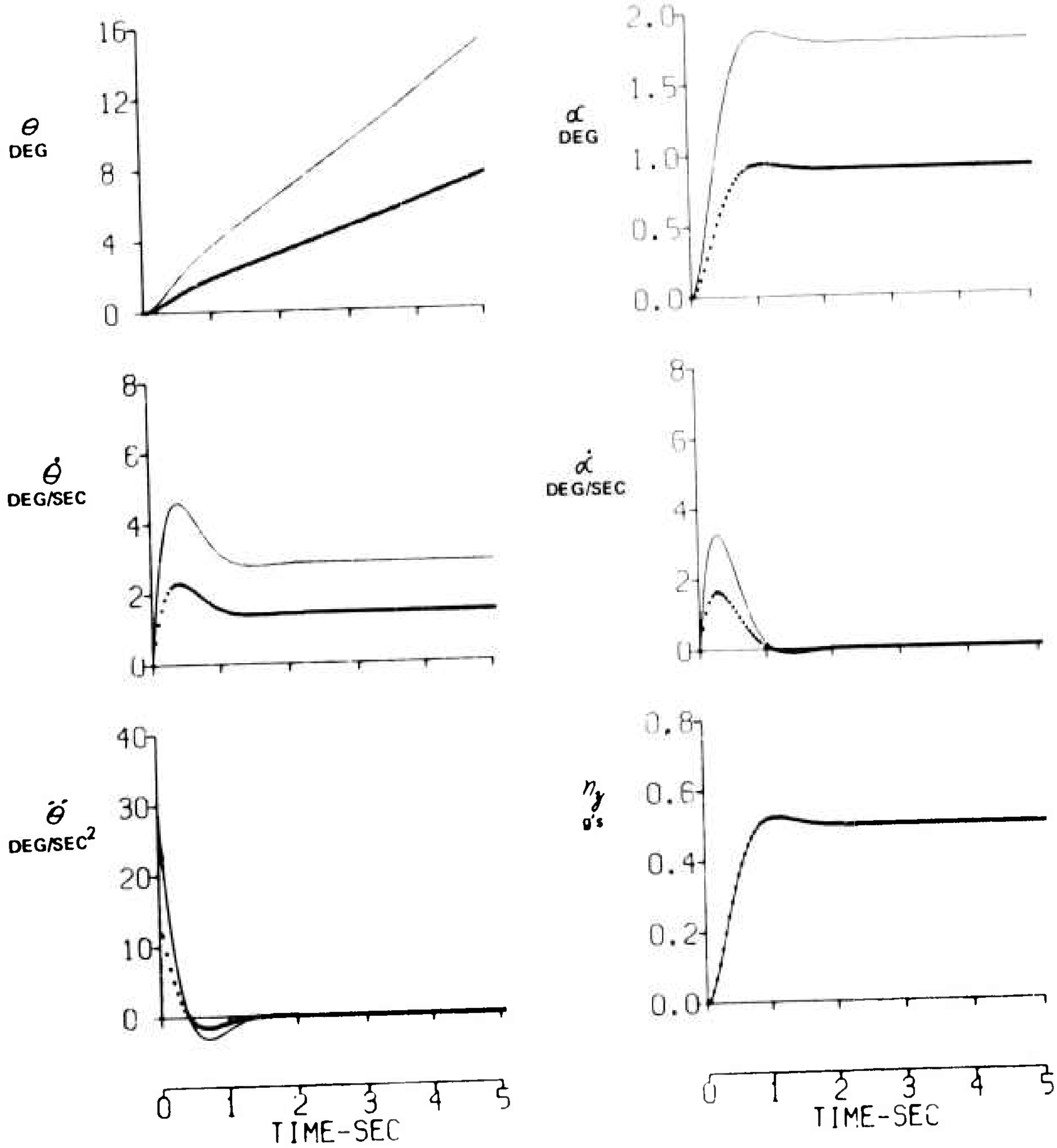


Figure 2 EFFECT OF VARYING VELOCITY ON RESPONSE TO ELEVATOR STEP INPUT

	ω_{sp}	ζ_{sp}	$1/T_{\theta_2}$	V
————	4 RAD/SEC	0.7	1.6 SEC^{-1}	322 FT/SEC
xxxxxxxxx	4 RAD/SEC	0.7	3.2 SEC^{-1}	644 FT/SEC

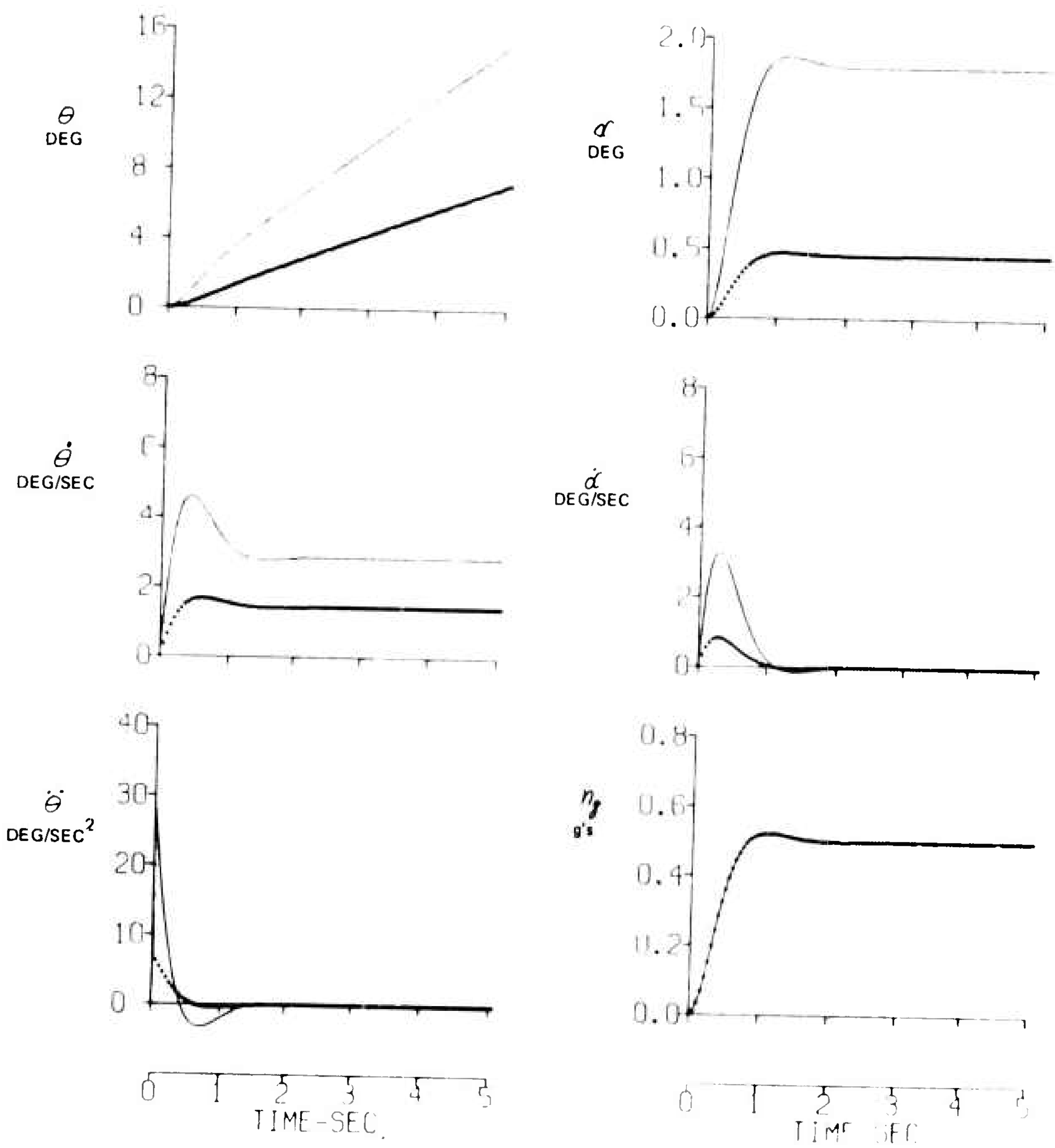


Figure 3 EFFECT OF VARYING $1/T_{\theta_2}$ AND VELOCITY ON RESPONSE TO ELEVATOR STEP INPUT

	ω_{sp}	ζ_{sp}	$1/T_{\theta_2}$	V
—————	4 RAD/SEC	0.7	1.6 SEC^{-1}	322 FT/SEC
xxxxxxxxxx	8 RAD/SEC	0.7	1.6 SEC^{-1}	322 FT/SEC

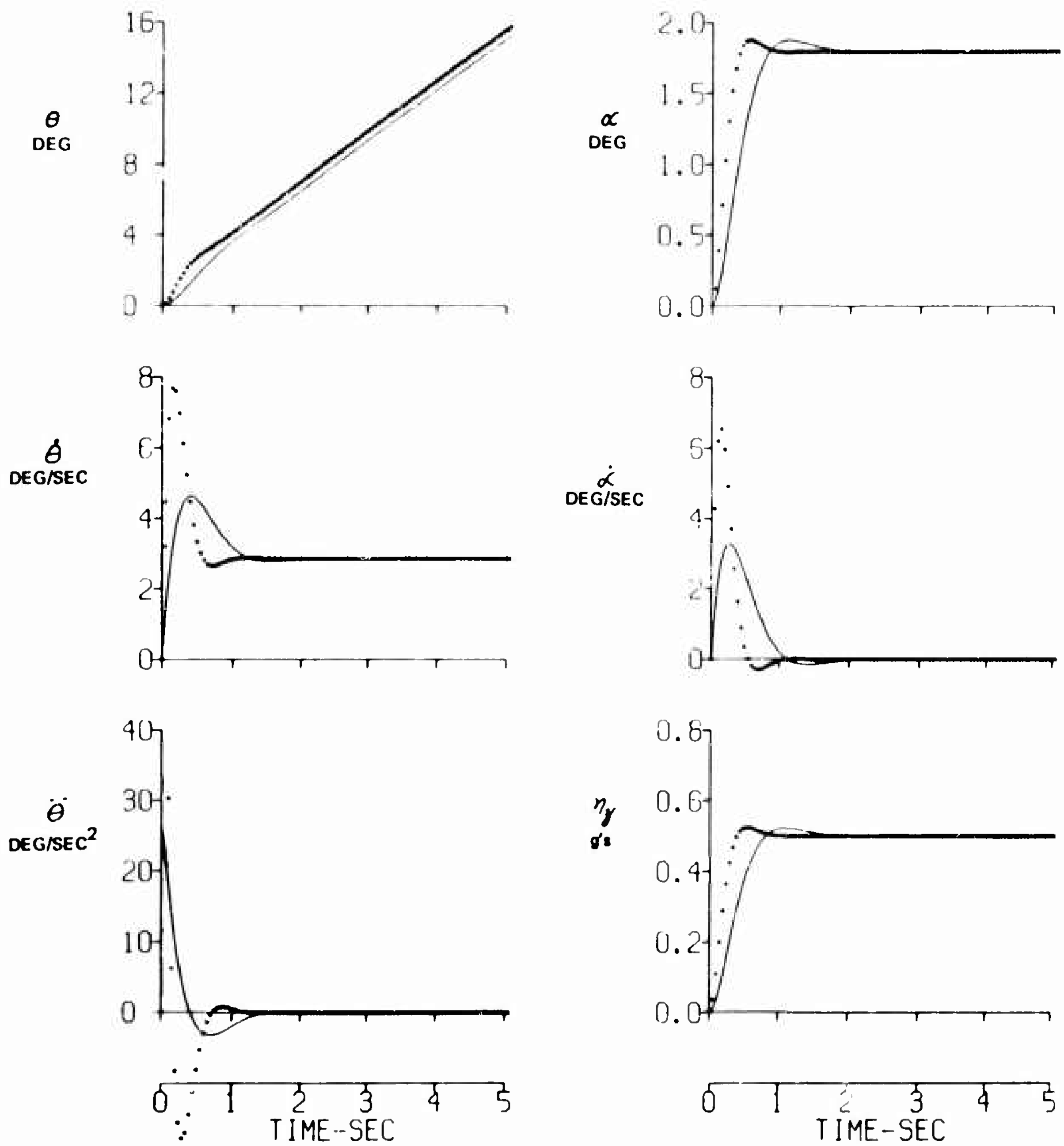


Figure 4 EFFECT OF VARYING ω_{sp} ON RESPONSE TO ELEVATOR STEP INPUT

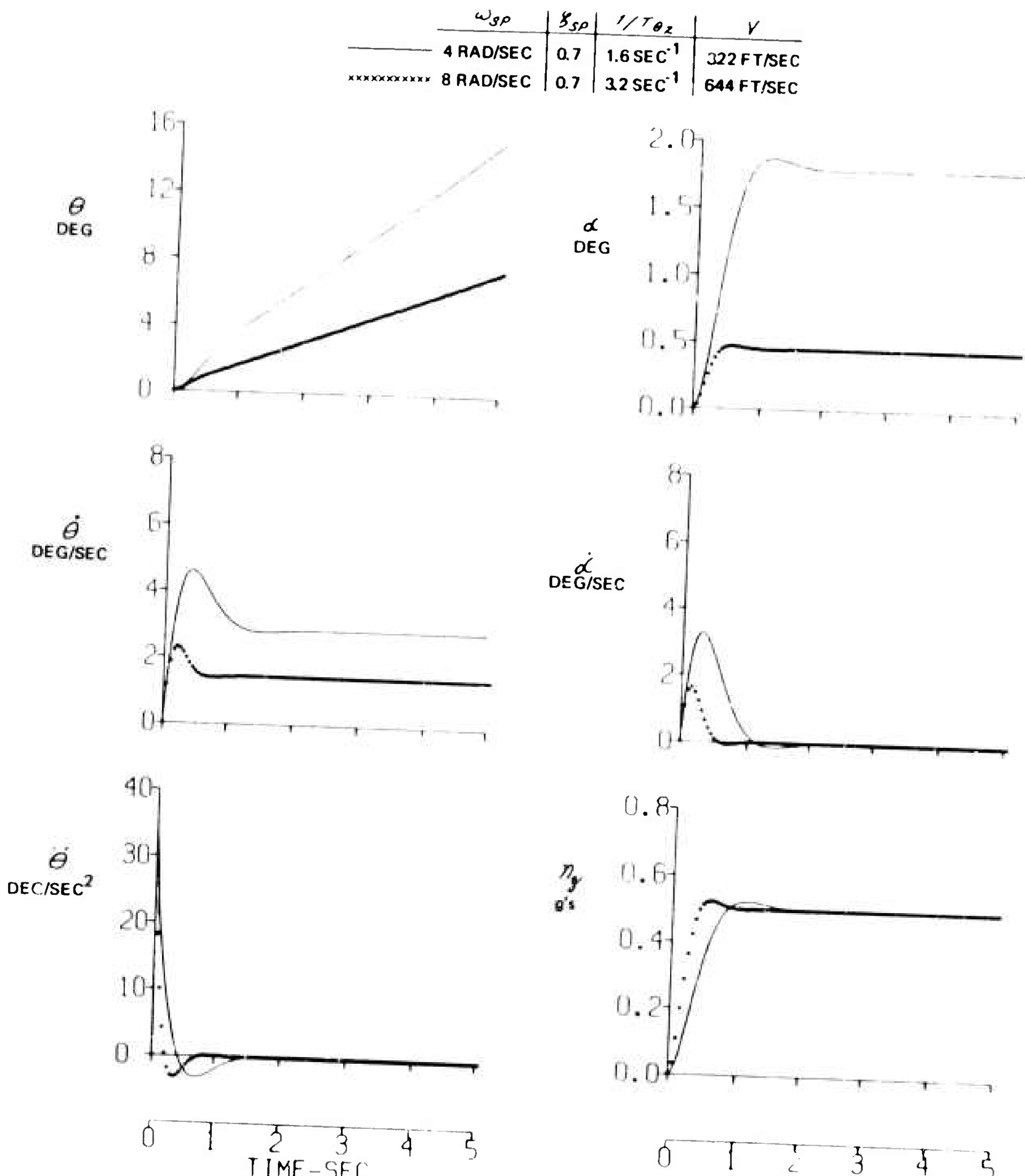


Figure 5 EFFECT OF VARYING ω_{sp}, $1/T_{\theta_2}$ AND VELOCITY ON RESPONSE TO ELEVATOR STEP INPUT

Figure 6 USAF/CAL VARIABLE STABILITY T-33 AIRCRAFT

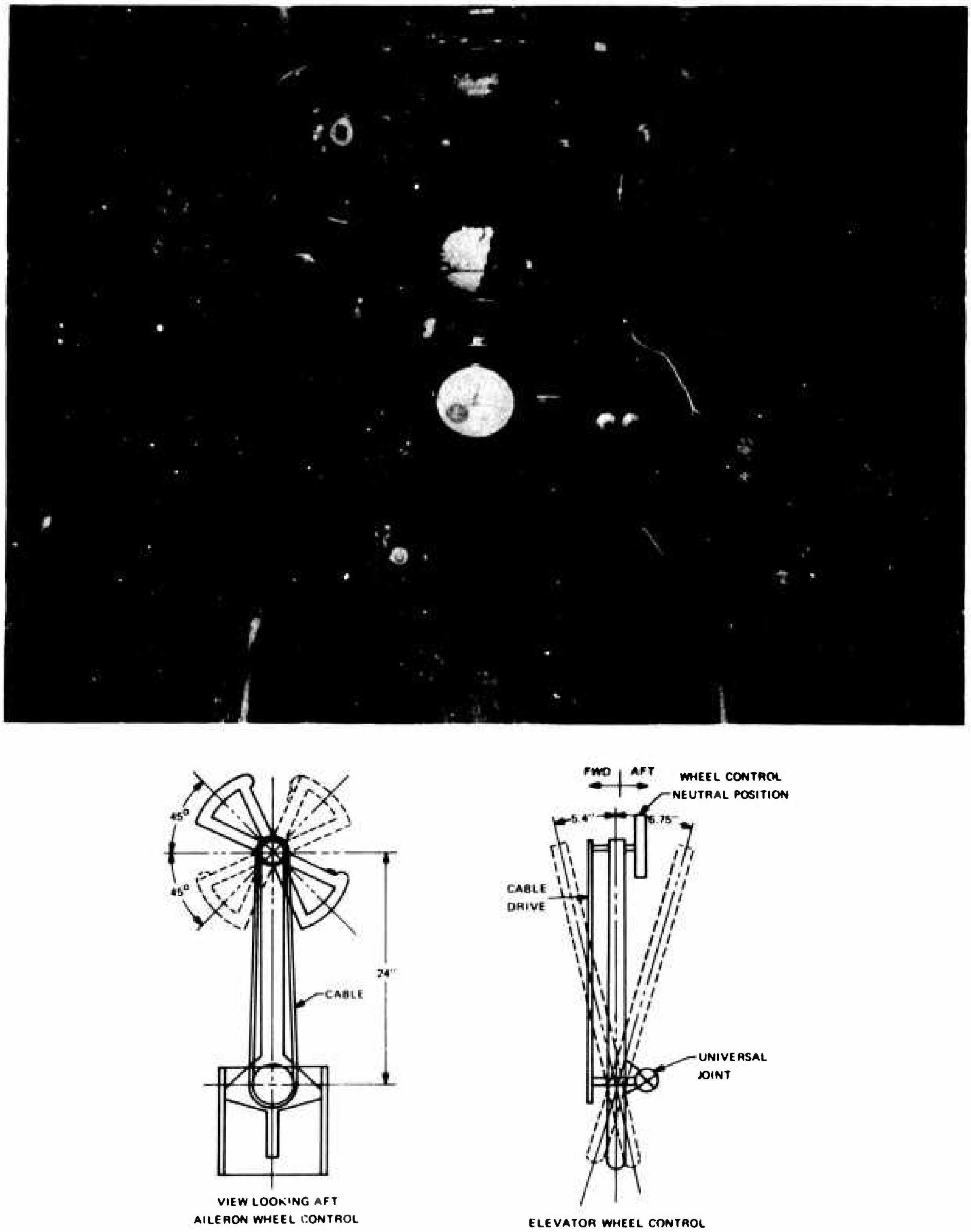
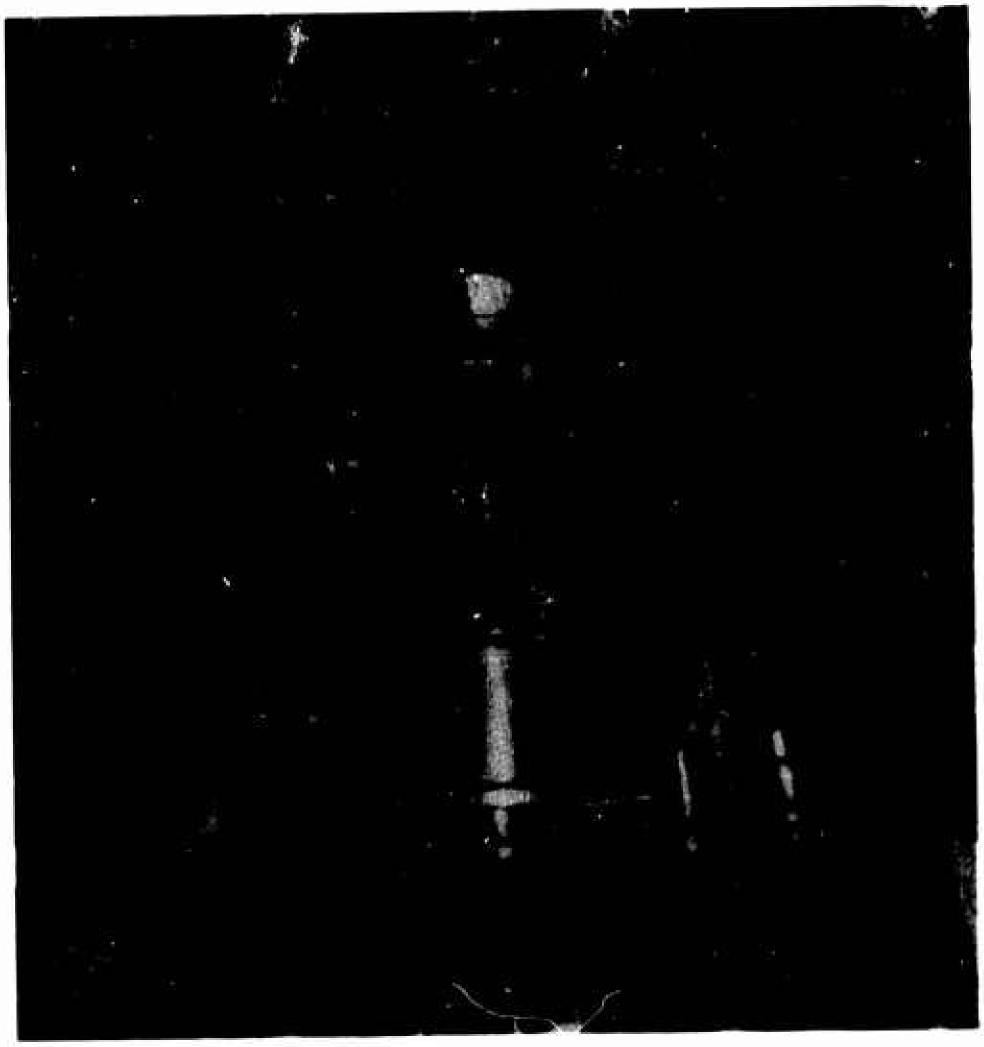


Figure 7 WHEEL INSTALLATION IN VARIABLE STABILITY T-33 COCKPIT



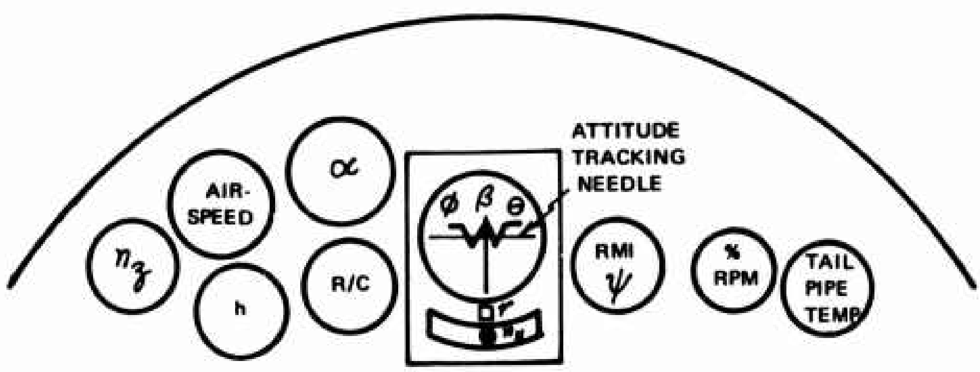


Figure 8 EVALUATION PILOT'S COCKPIT IN VARIABLE STABILITY T-33

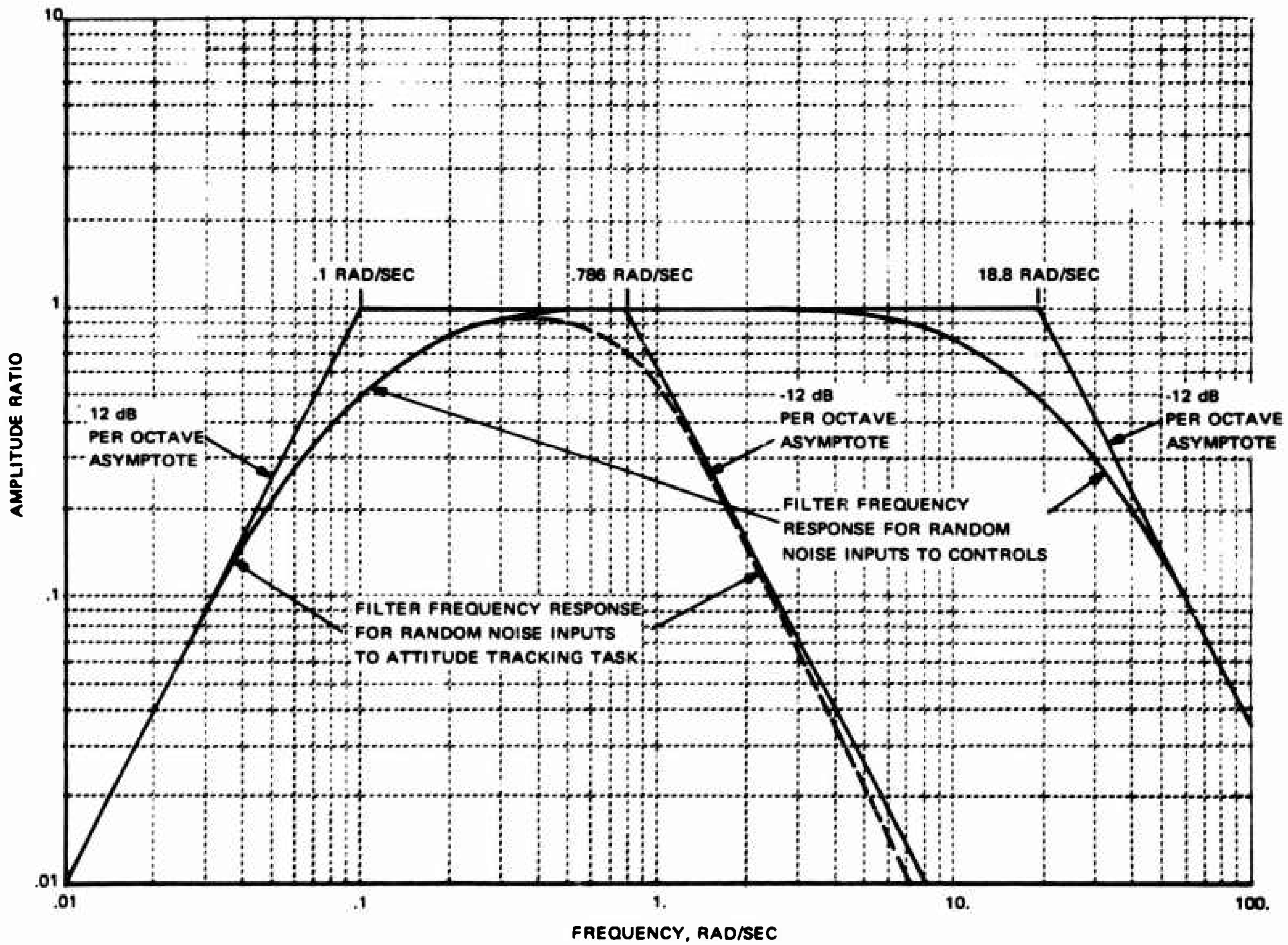


Figure 9 RANDOM NOISE FILTER FREQUENCY RESPONSE

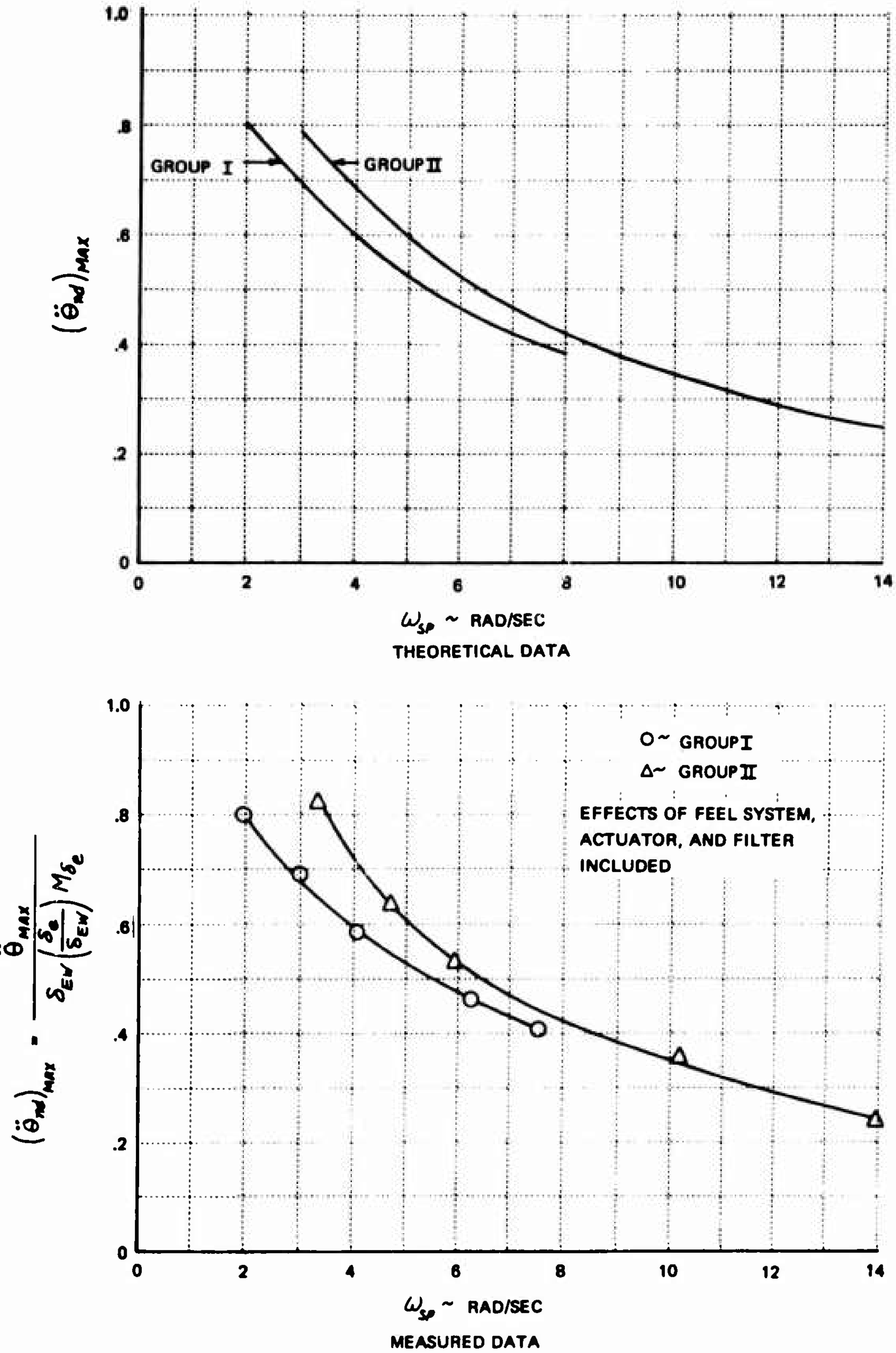


Figure 10 ATTENUATION OF THE $\ddot{\theta}_{MAX}$ RESPONSE TO A STEP WHEEL FORCE COMMAND DUE TO THE ELEVATOR FEEL SYSTEM AND ACTUATOR DYNAMICS

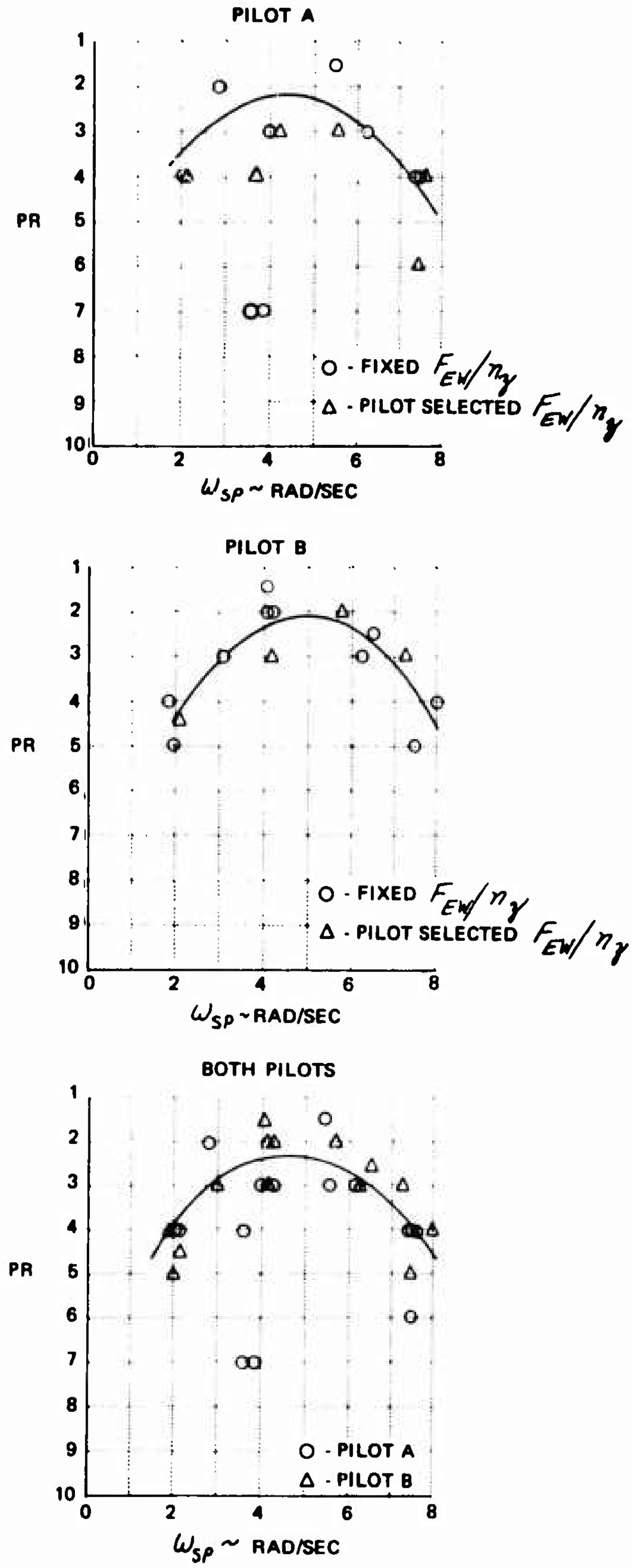


Figure 11 PILOT RATING VS. ω_{SP} FOR GROUP I ($n_z/\alpha \approx 16.5$, $1/T_{\theta_2} \approx 1.19$, V_T = 411 FT/SEC)

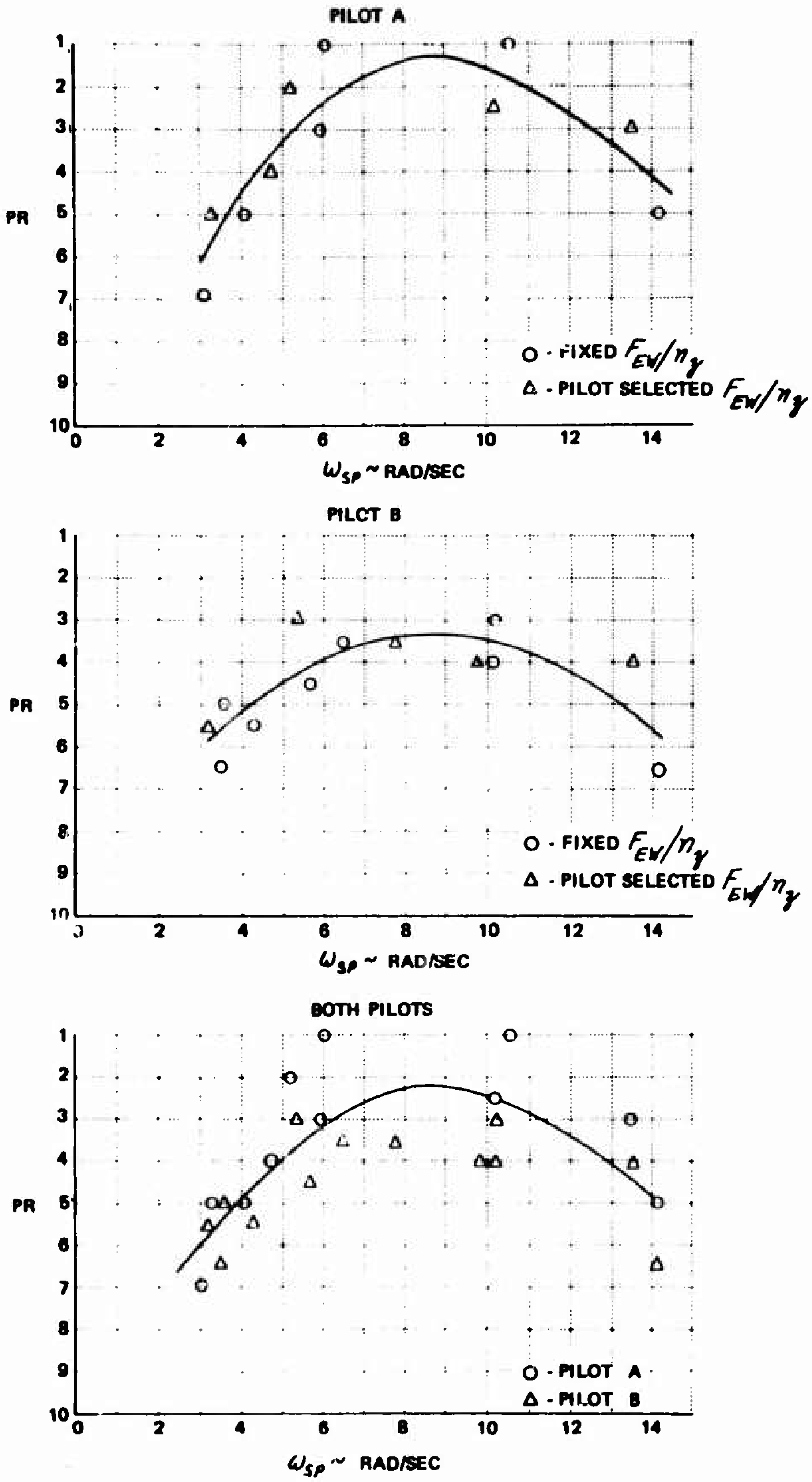


Figure 12. PILOT RATING VS. ω_{SP} FOR GROUP II ($n_y/\alpha \approx 56.2$, $1/T_{\theta_2} \approx 2.65$, V_T = 685 FT/SEC)

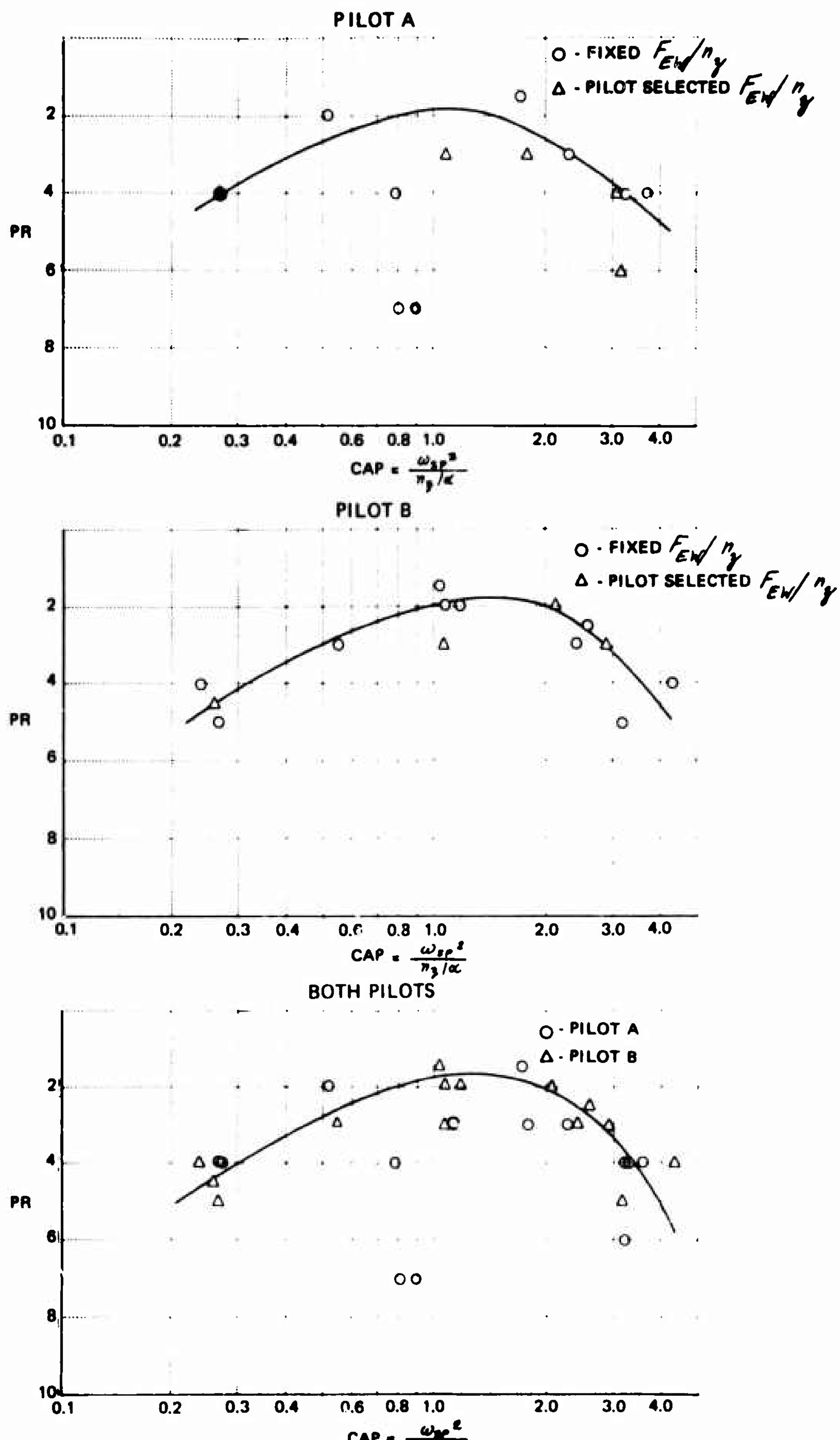


Figure 13 PILOT RATING VS. CAP FOR GROUP I

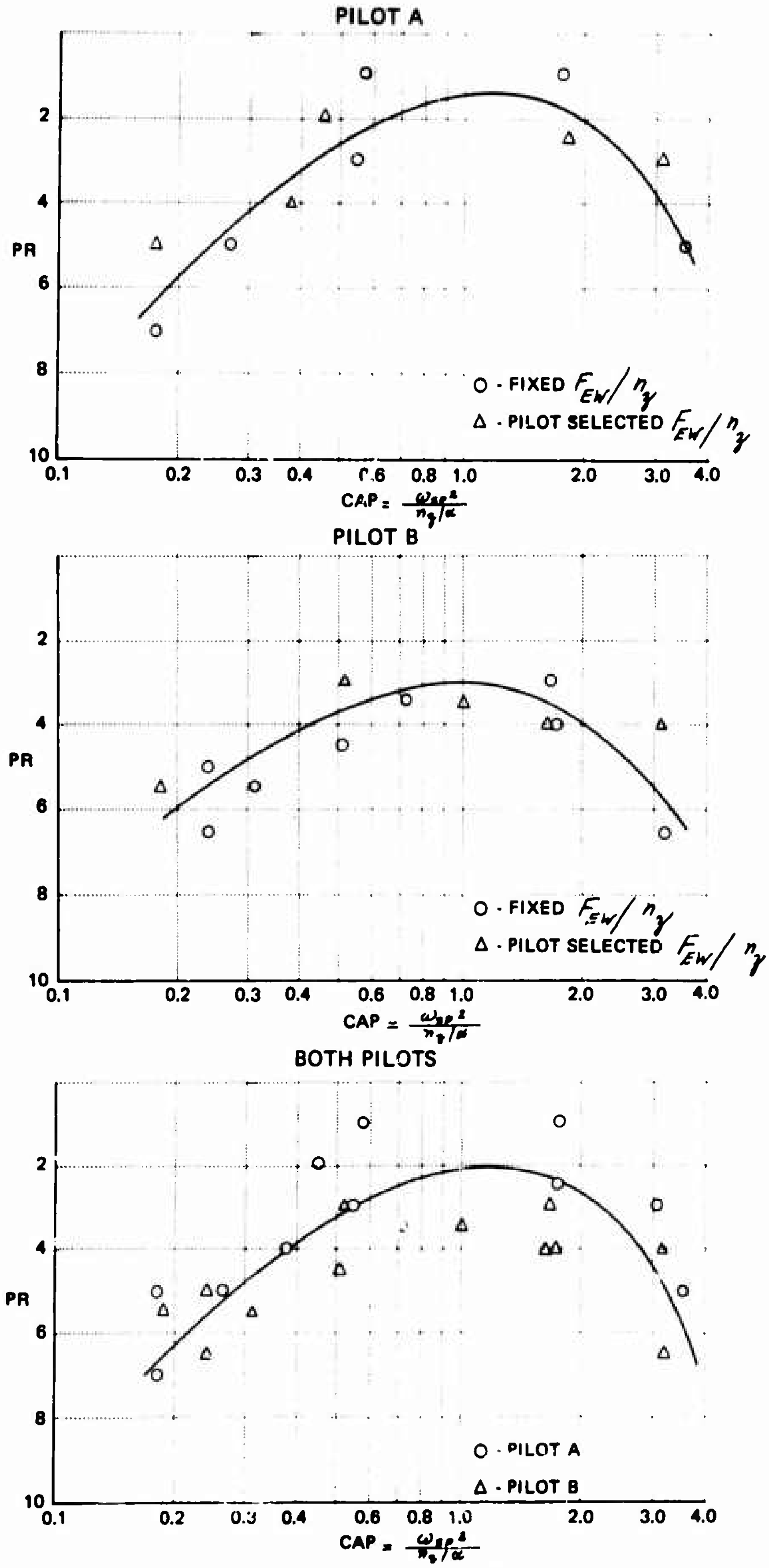


Figure 14 PILOT RATING VS. CAP FOR GROUP II

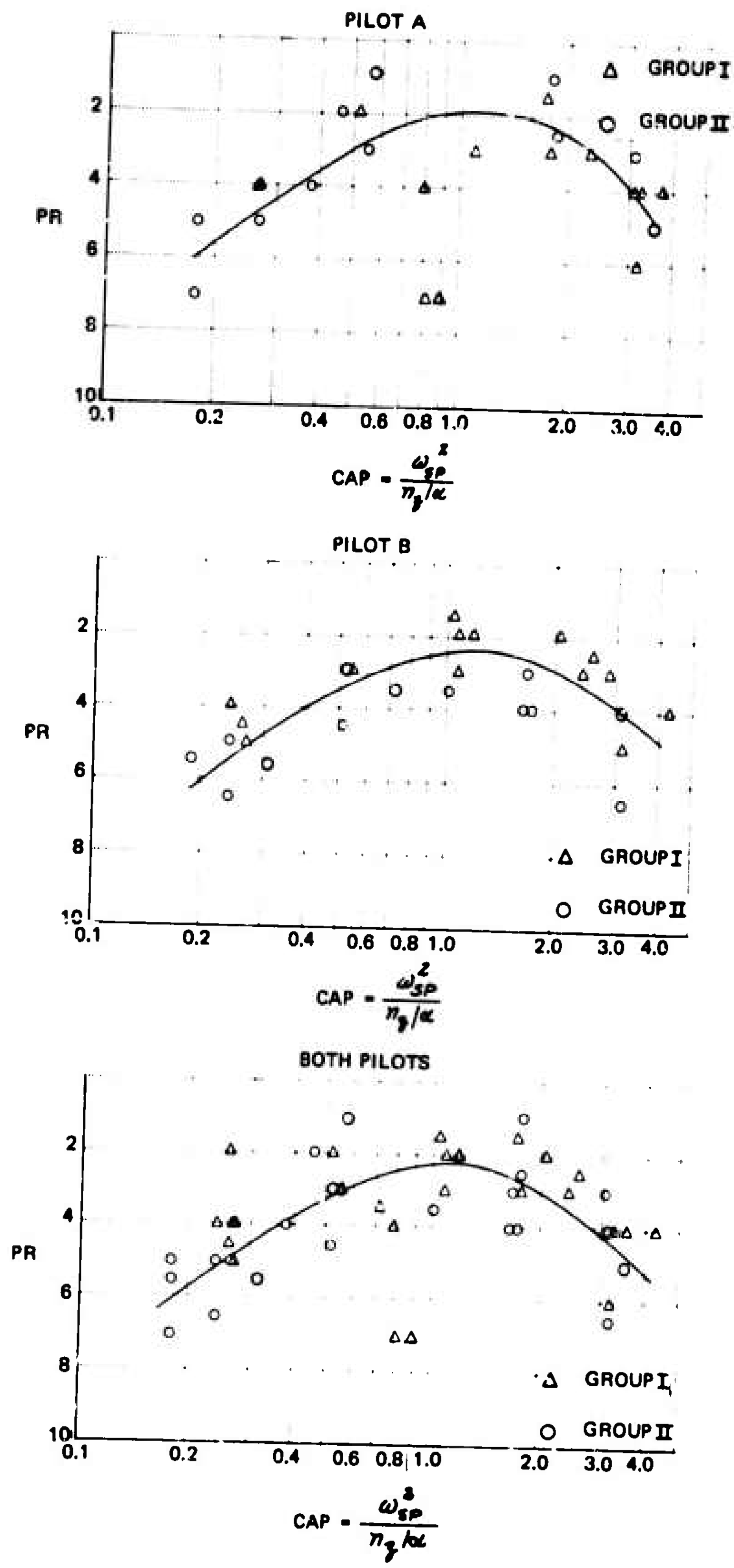


Figure 15 PILOT RATING VS. CAP FOR BOTH DATA GROUPS

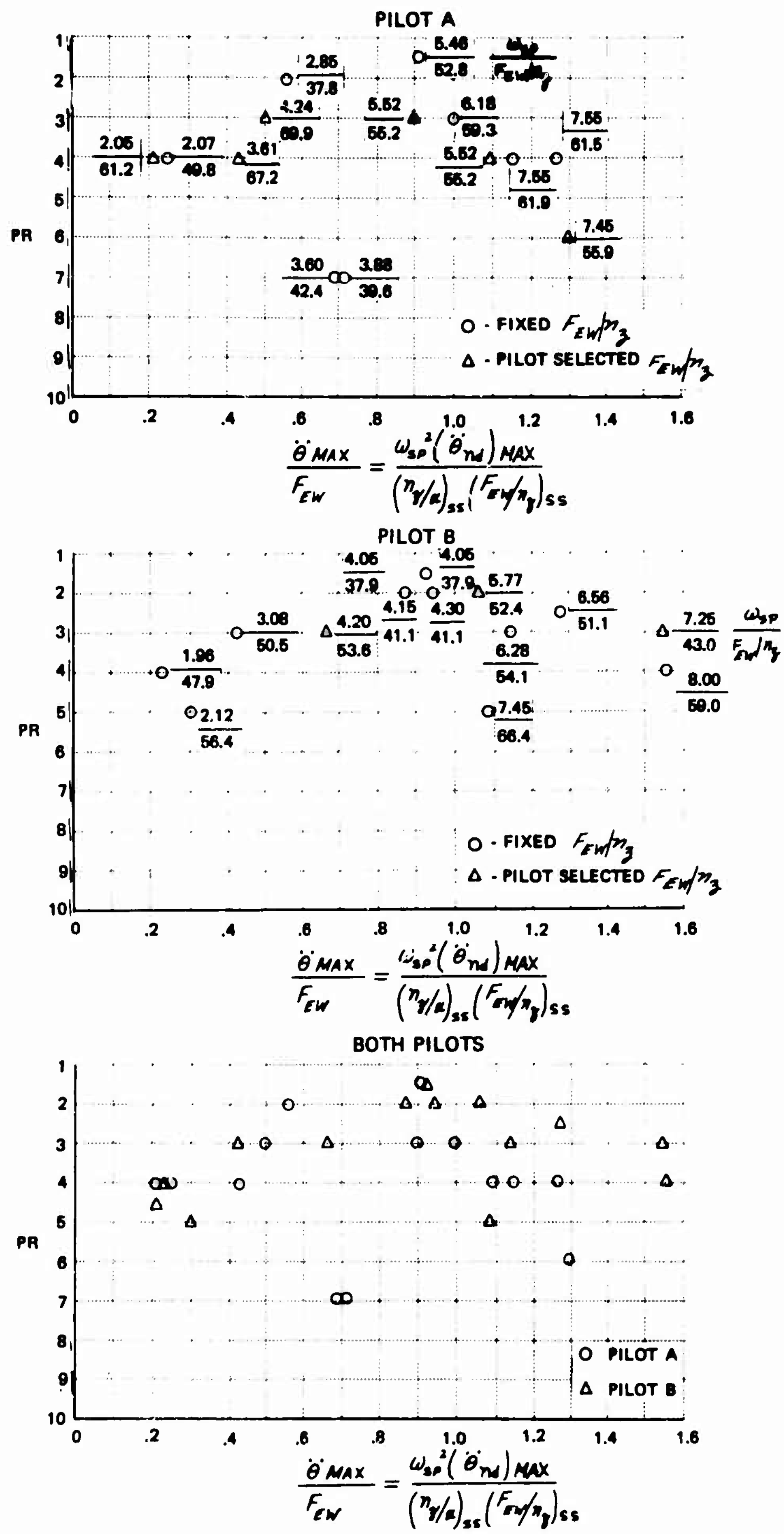


Figure 16 PILOT RATING VS. $\ddot{\theta}_{MAX}/F_{EW}$ FOR GROUP I

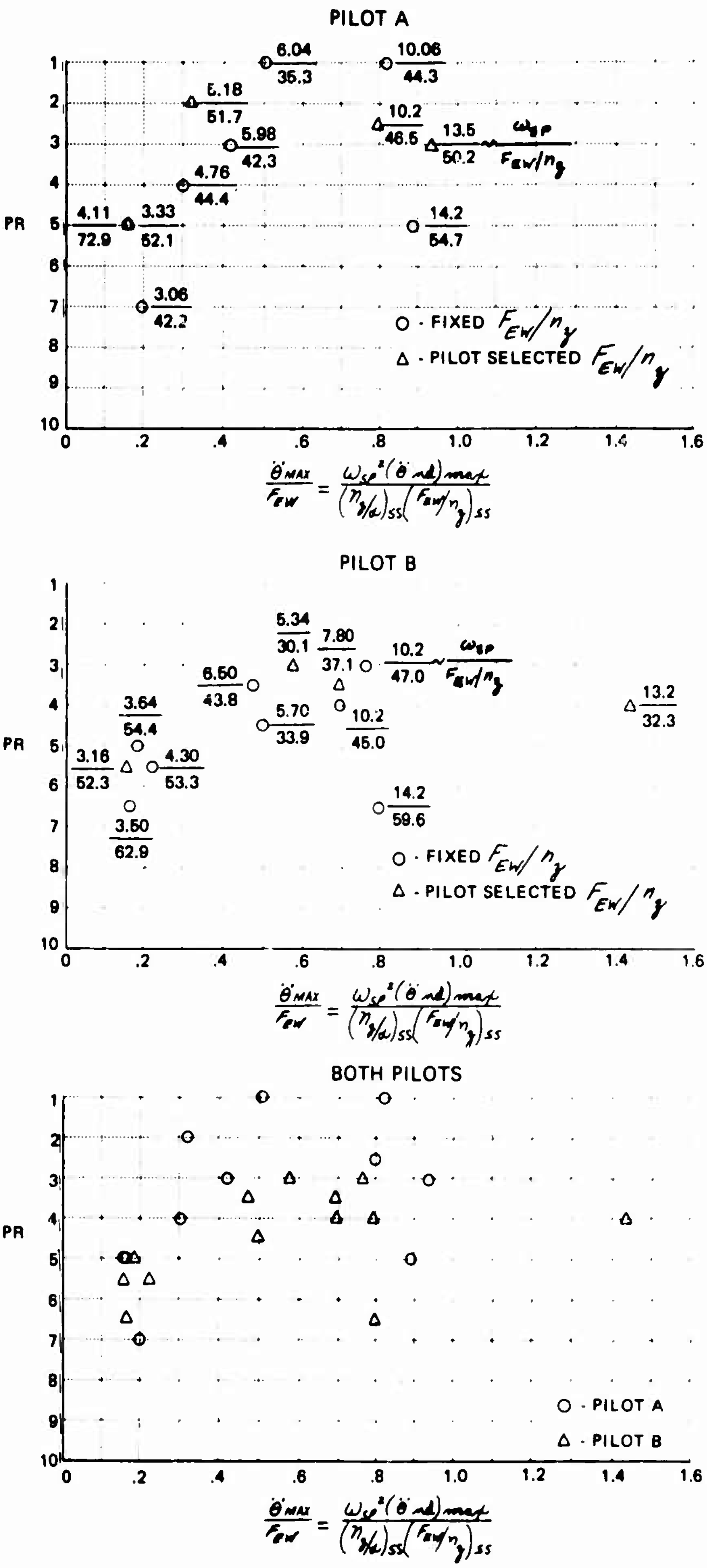


Figure 17 PILOT RATING VS. $\ddot\theta_{MAX}/F_{EW}$ FOR GROUP II

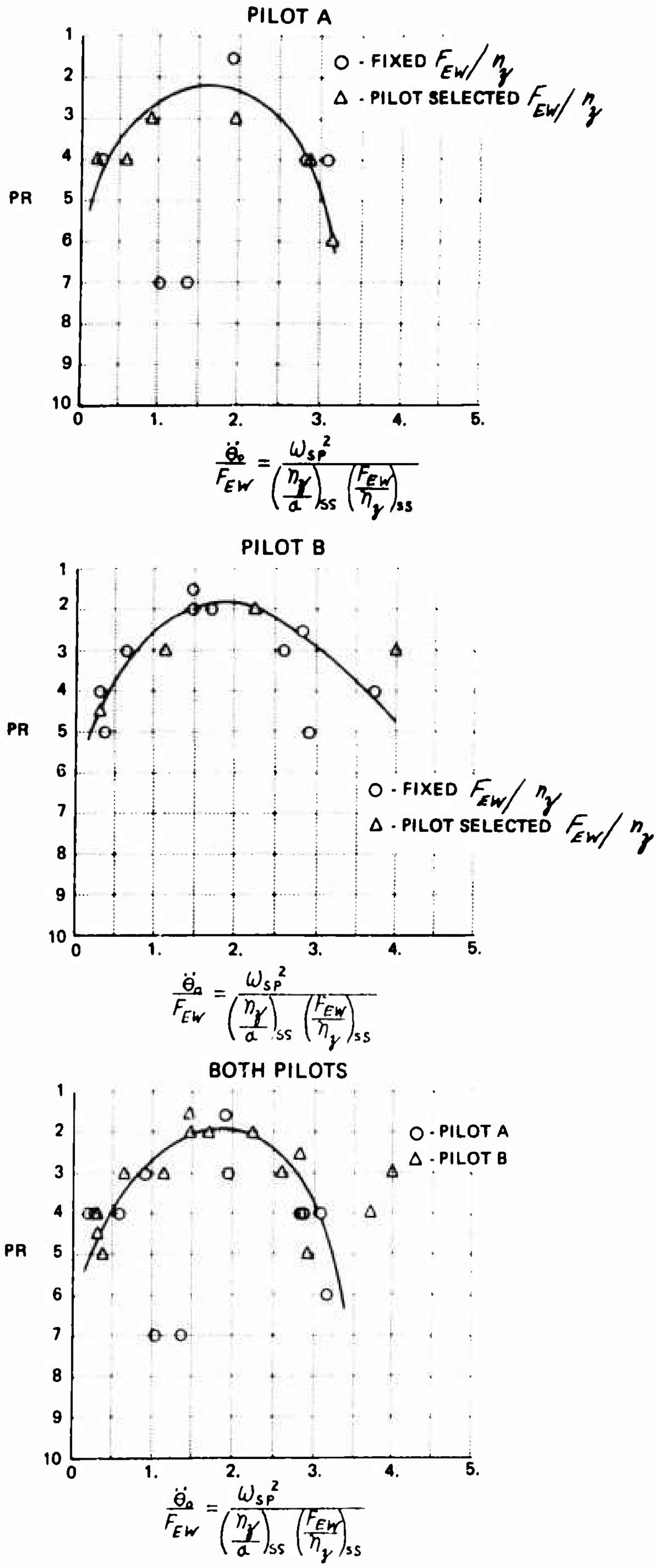


Figure 18 PILOT RATING VS. $\ddot{\theta}_o/F_{EW}$ FOR GROUP I

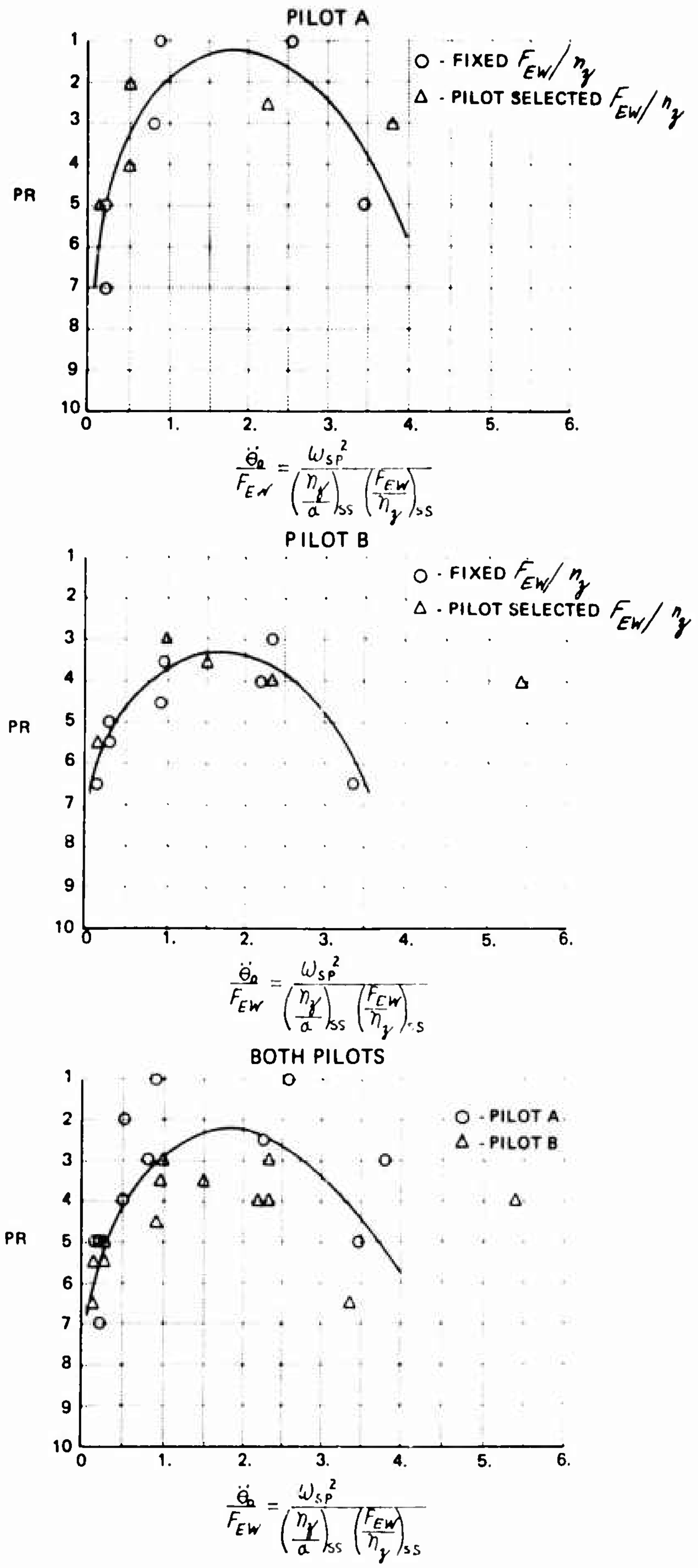
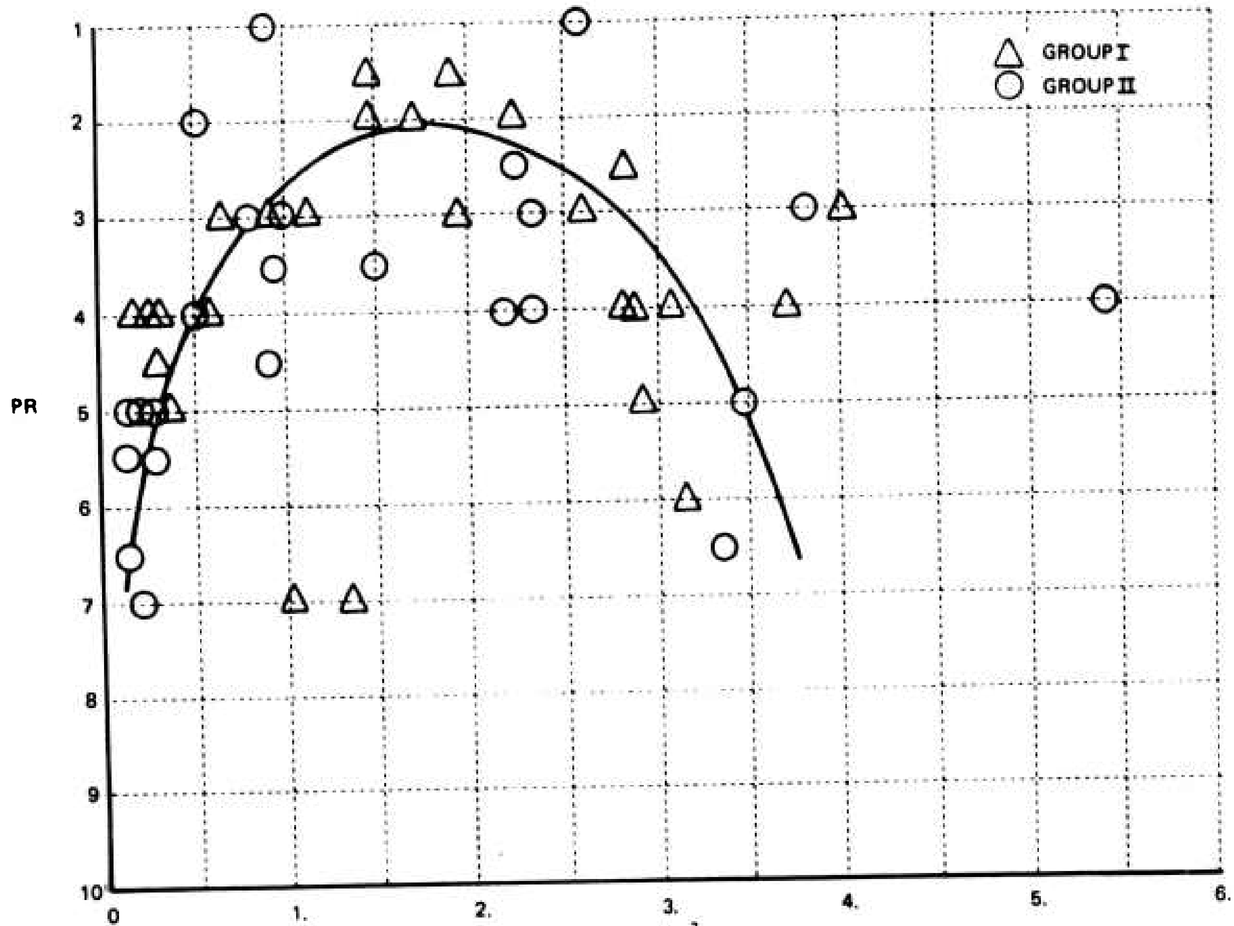


Figure 19 PILOT RATING VS. $\ddot{\theta}_o/F_{EW}$ FOR GROUP II



$$\frac{\ddot{\theta}_o}{F_{EW}} = \frac{\omega_{sp}^2}{\left(\frac{n_z}{\alpha}\right)_{ss}\left(\frac{F_{EW}}{n_z}\right)_{ss}}$$

Figure 20 PILOT RATINGS FOR BOTH PILOTS VS. $\ddot{\theta}_o / F_{EW}$ FOR BOTH DATA GROUPS

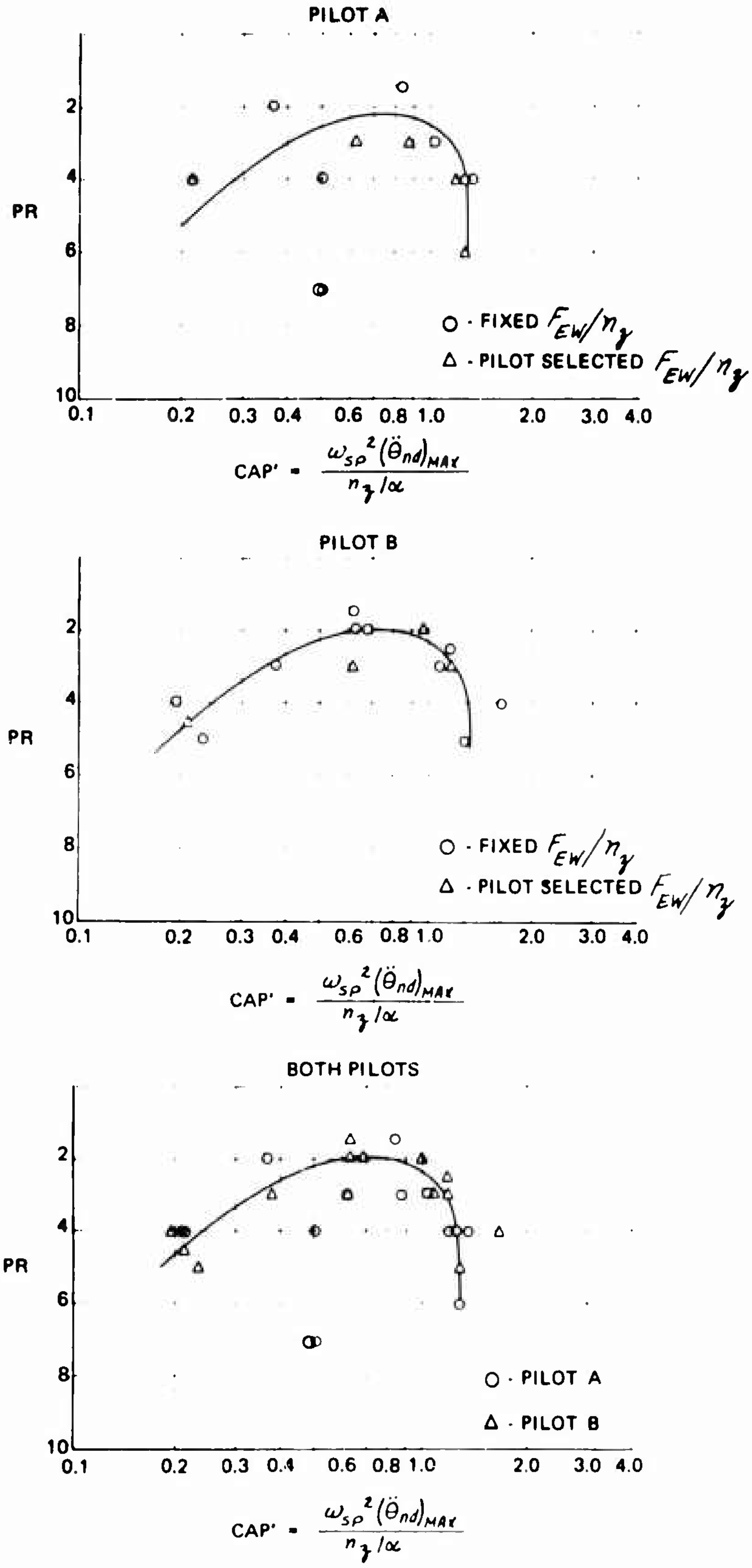


Figure 21 PILOT RATING VS. CAP' FOR GROUP I

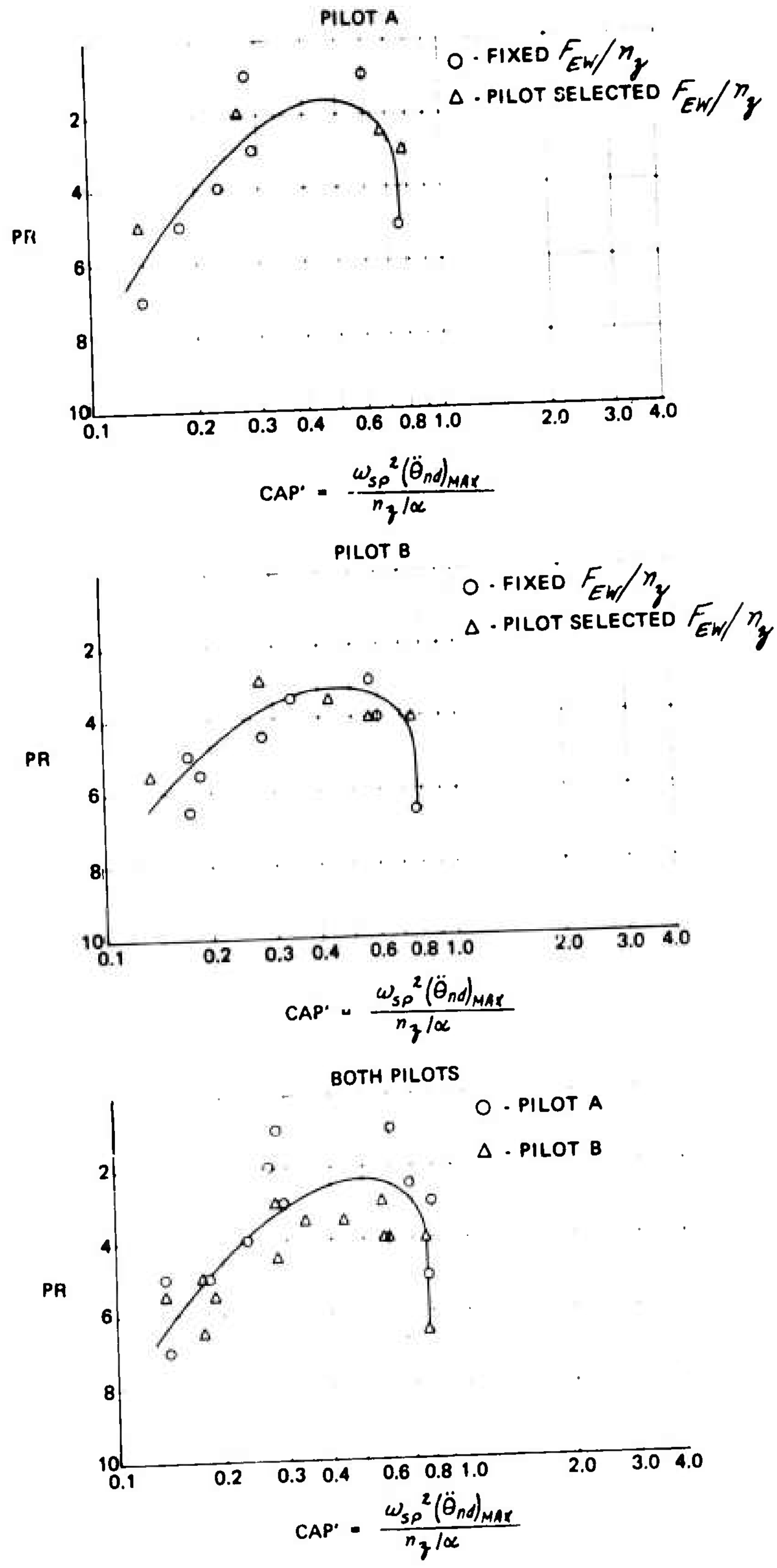


Figure 22 PILOT RATING VS. CAP' FOR GROUP II

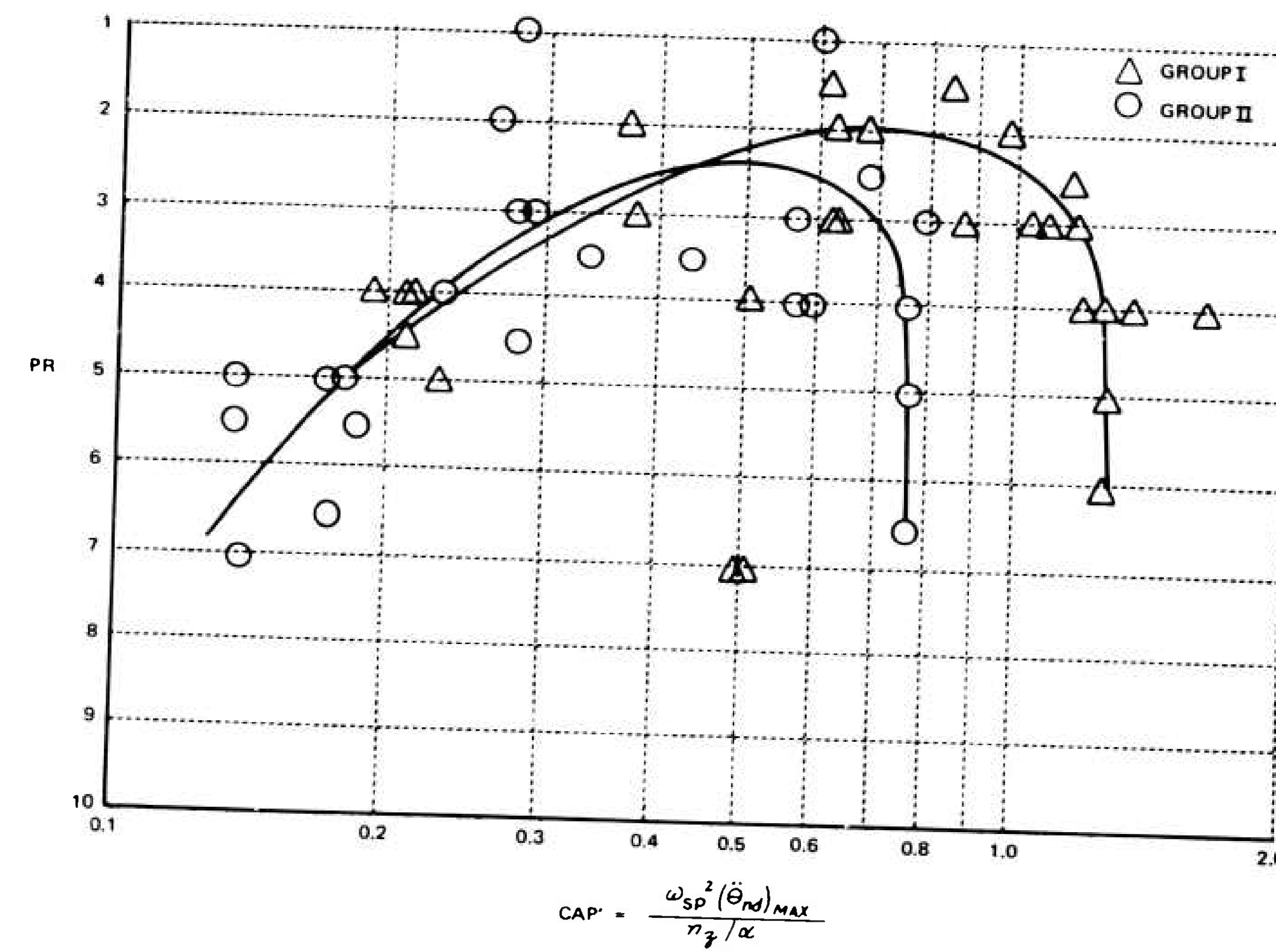


Figure 23 PILOT RATING FOR BOTH PILOTS VS. CAP' FOR BOTH DATA GROUPS

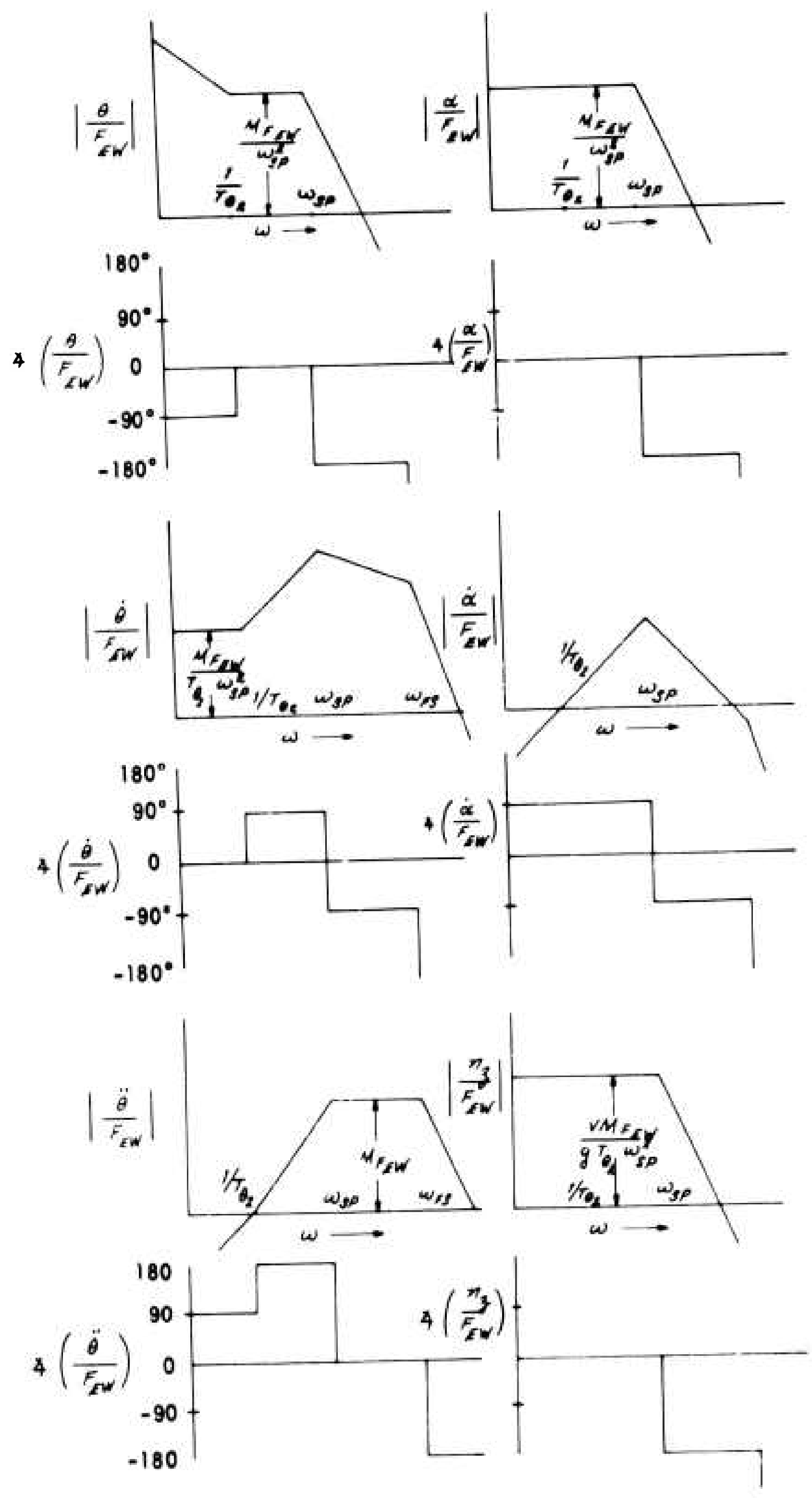


Figure 24 ASYMPTOTIC BODE PLOT REPRESENTATIONS OF THE LONGITUDINAL TRANSFER FUNCTIONS

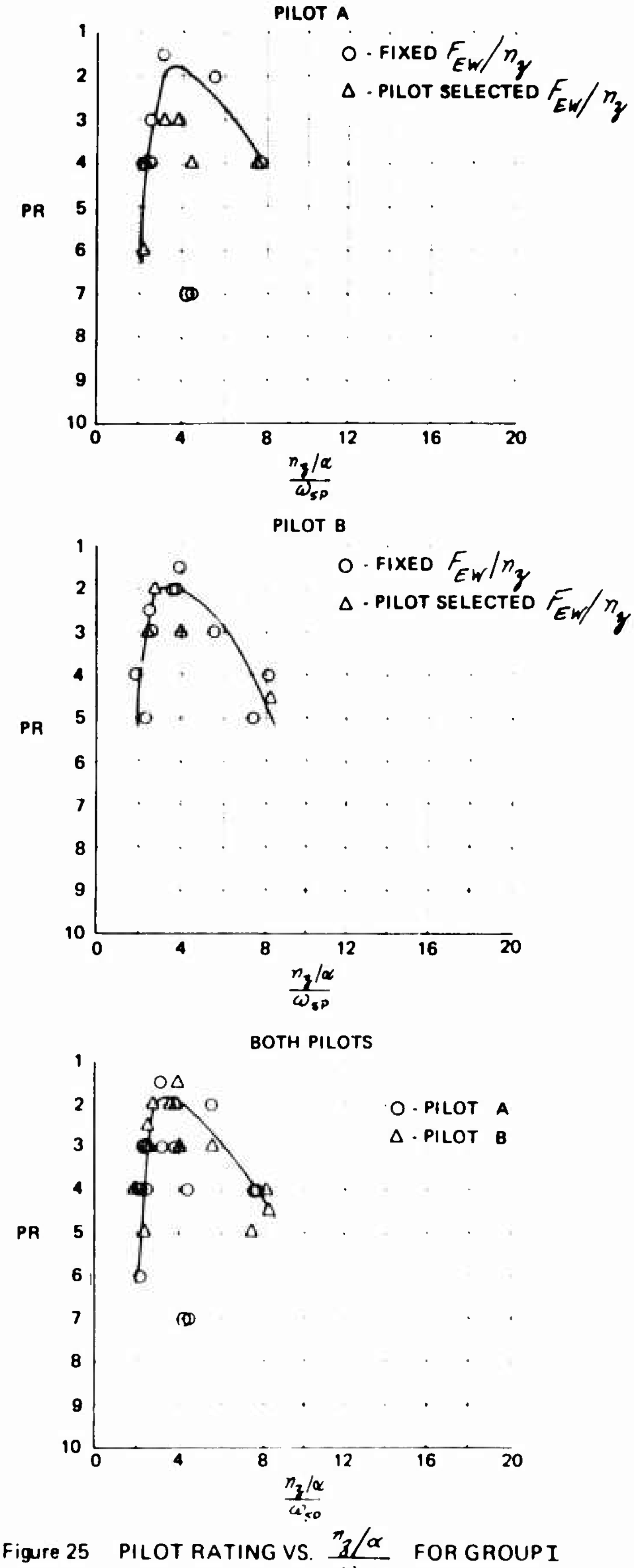


Figure 25 PILOT RATING VS. $\frac{n_z/\alpha}{\omega_{sp}}$ FOR GROUP I

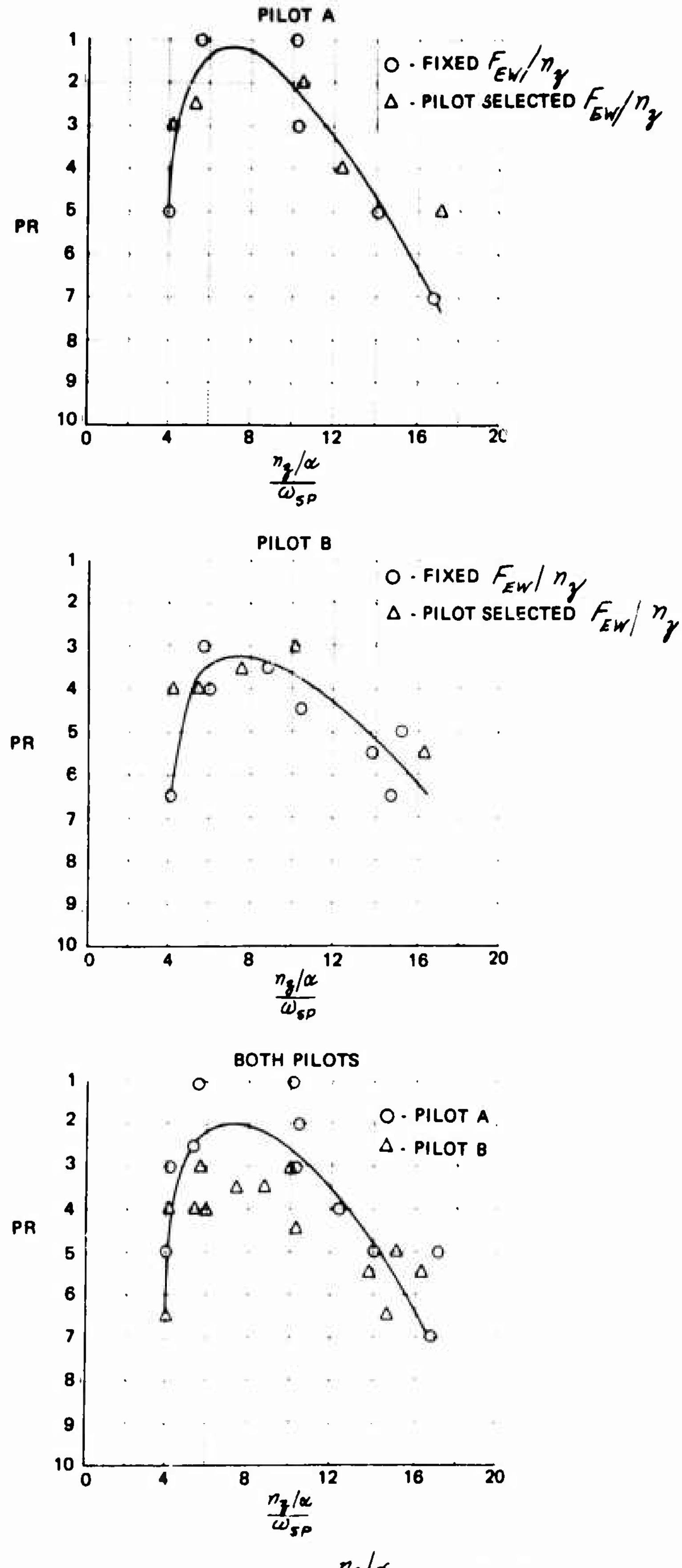
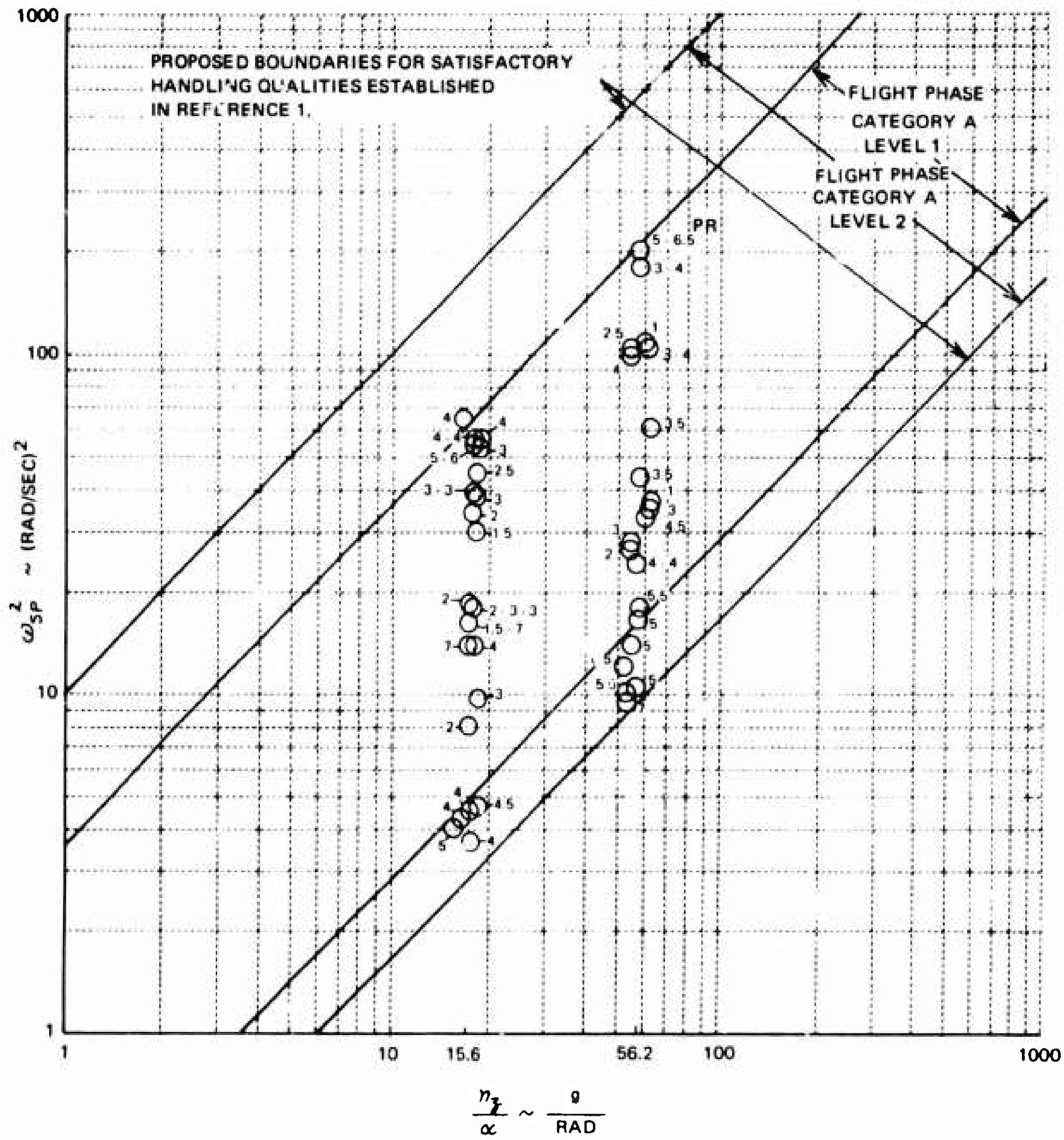
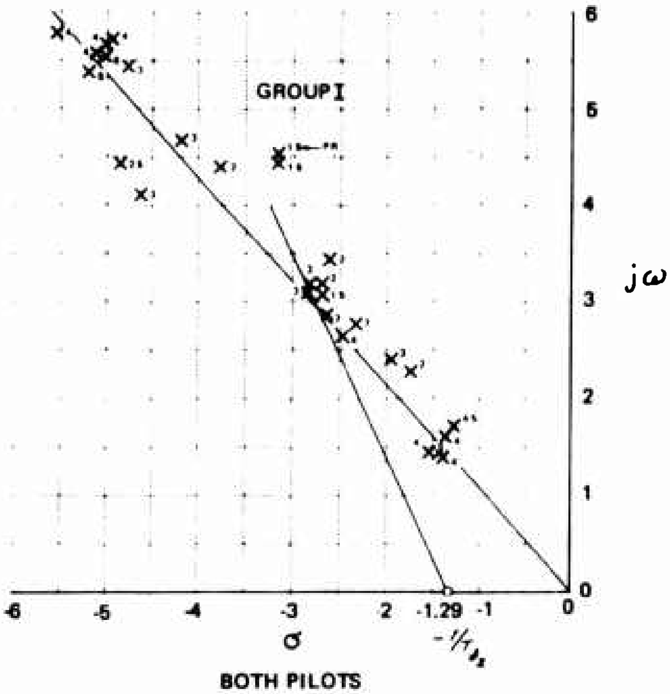


Figure 26 PILOT RATING VS. $\frac{n_z/\alpha}{\omega_{SP}}$ FOR GROUP II



BOTH PILOTS (FLIGHT DATA)

Figure 27 COMPARISON OF PILOT RATING DATA WITH PROPOSED MIL-F-8785 SPECIFICATION REQUIREMENTS FOR ω_{SP}^2 VS. n_z/α



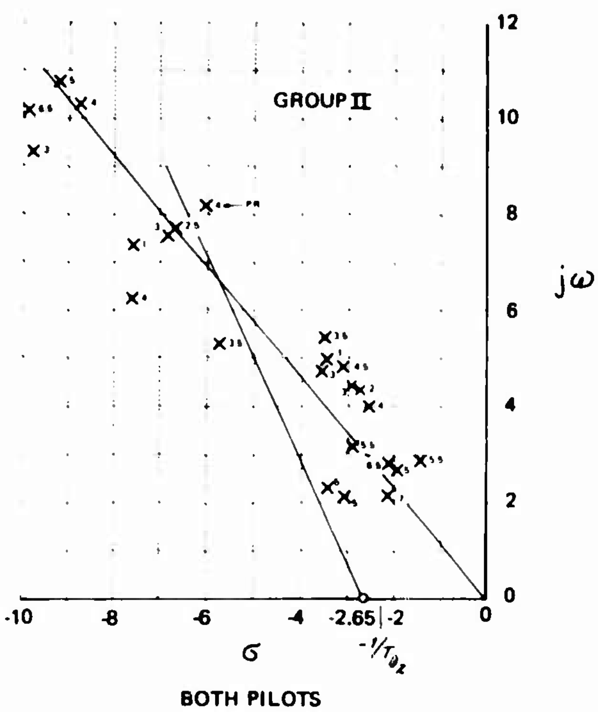


Figure 28 COMPARISON OF PHASE ANGLE OF OPTIMUM SHORT-PERIOD FREQUENCY FOR BOTH DATA GROUPS

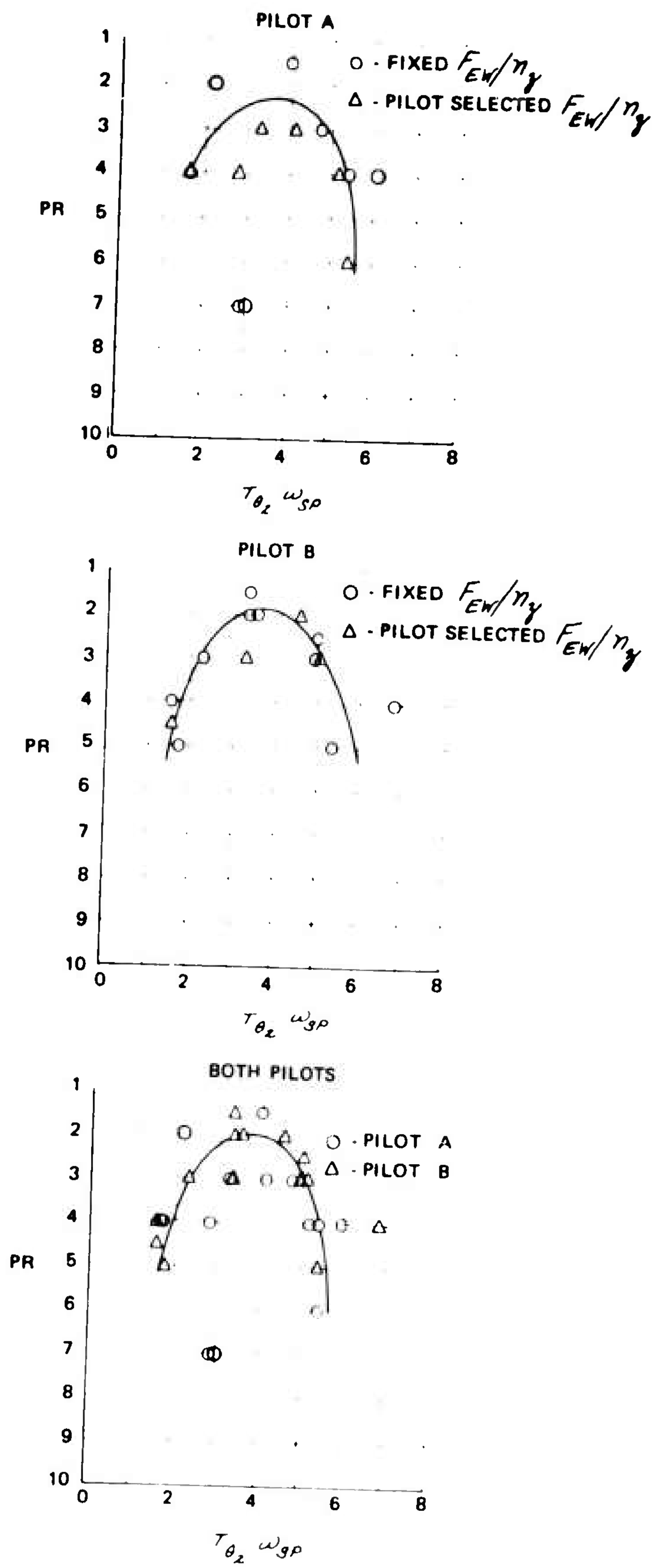


Figure 29 PILOT RATING VS. $T_{\theta_2} \omega_{SP}$ FOR GROUP I

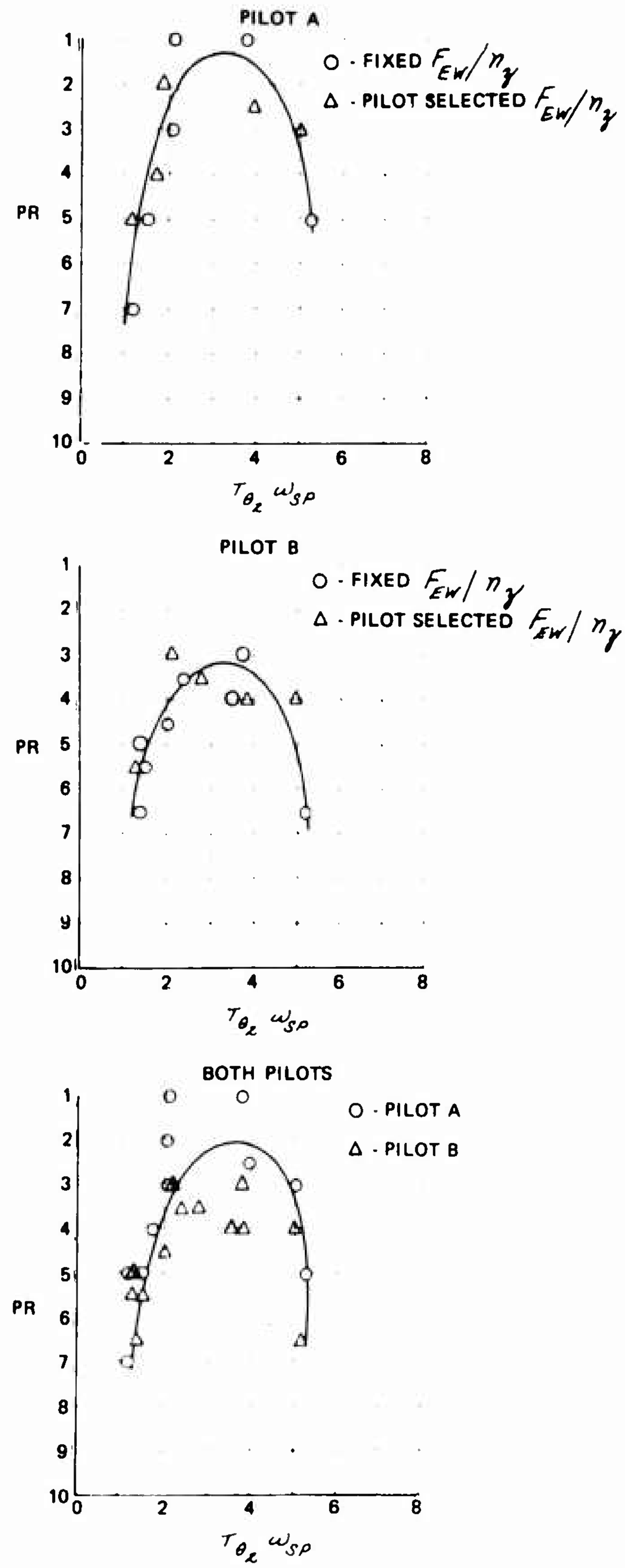


Figure 30 PILOT RATING VS. $T_{\theta_2}\ \omega_{SP}$ FOR GROUP II

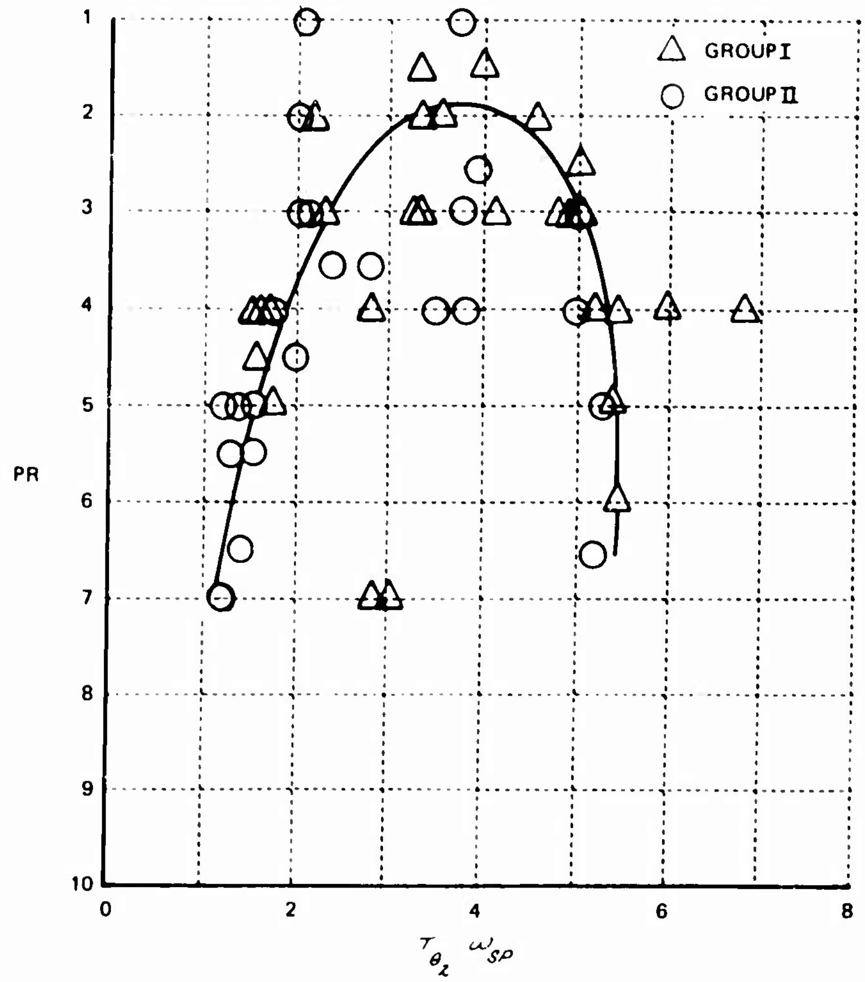


Figure 31 PILOT RATING FOR BOTH PILOTS VS. $\tau_{\theta_2}\ \omega_{sp}$ FOR BOTH DATA GROUPS

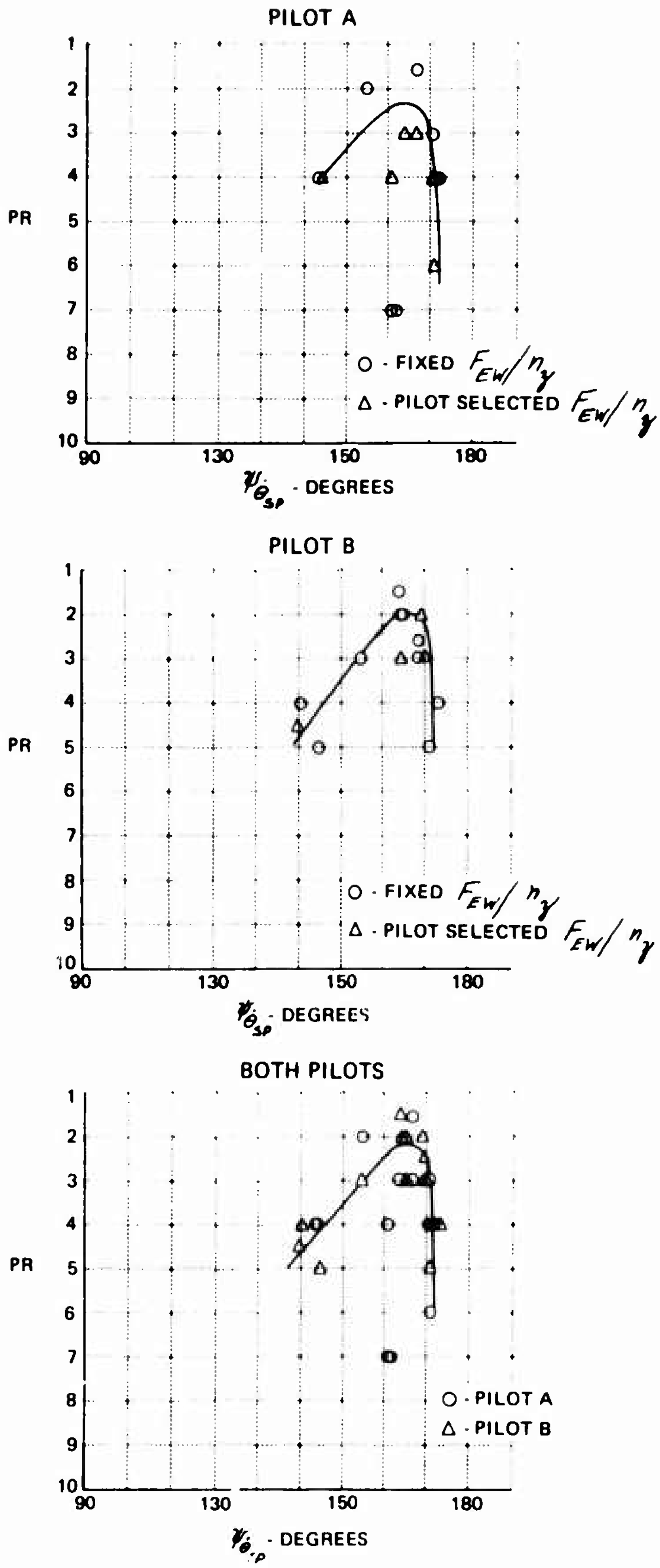


Figure 32 PILOT RATING VS. $\psi_{\dot\theta_{sp}}$ FOR GROUP I

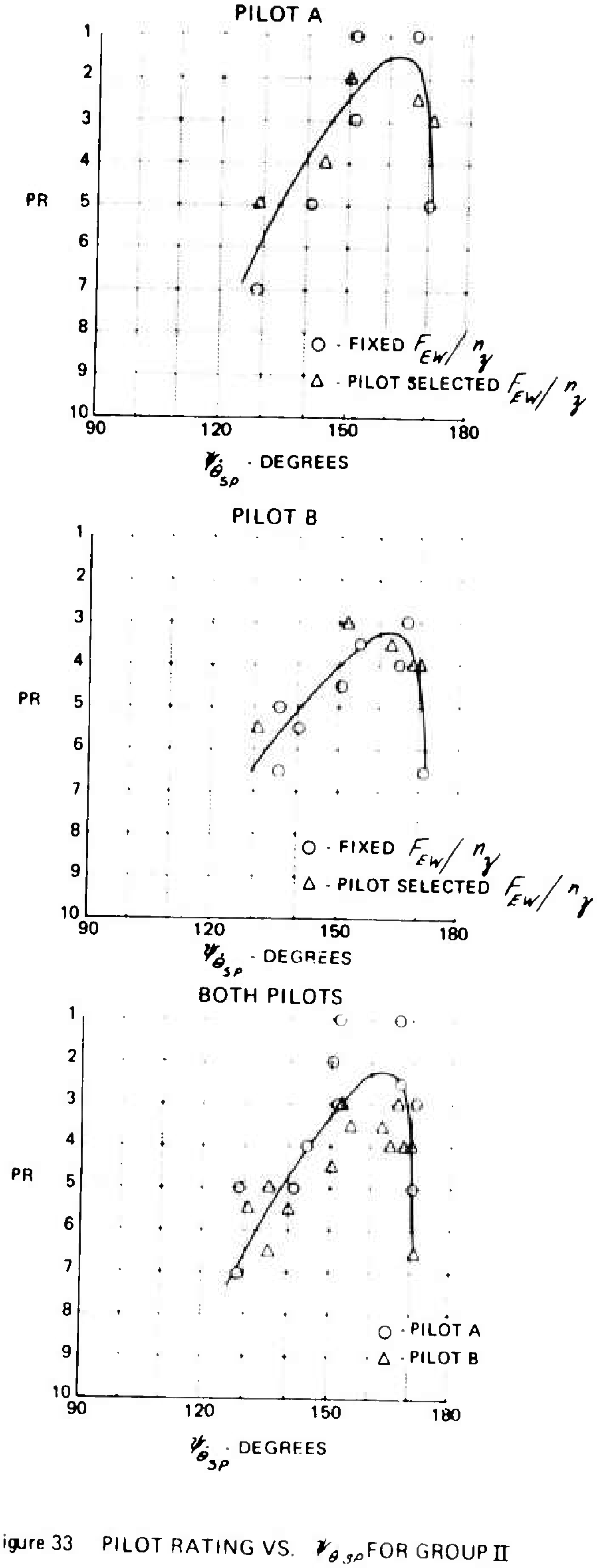


Figure 33 PILOT RATING VS. $\psi_{\theta_{sp}}$ FOR GROUP II

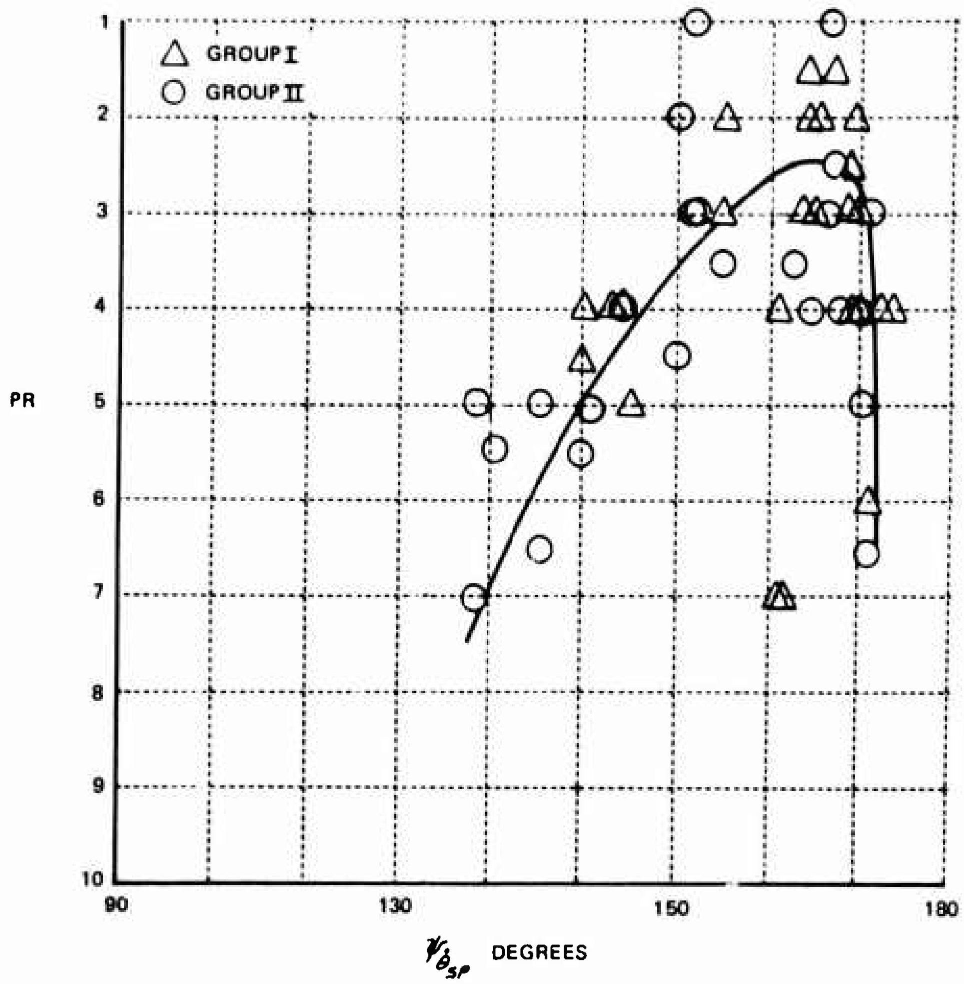


Figure 34 PILOT RATINGS FOR BOTH PILOTS VS. $\psi_{\dot{\theta}_{sp}}$ FOR BOTH DATA GROUPS

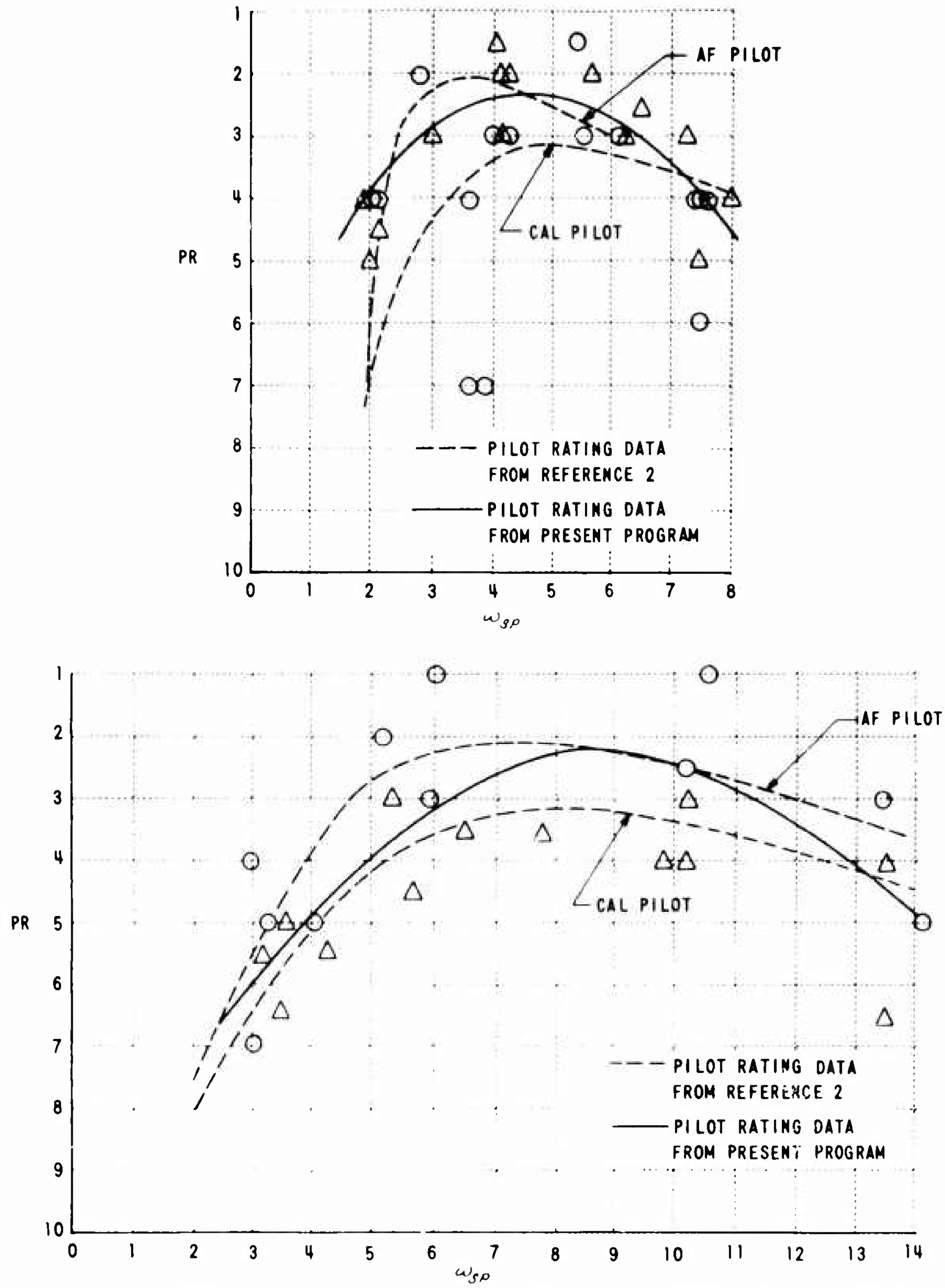


Figure 35 COMPARISON OF PILOT RATING DATA FROM REFERENCE 2 FOR A STICK-CONTROLLED AIRPLANE WITH WHEEL-CONTROLLED DATA

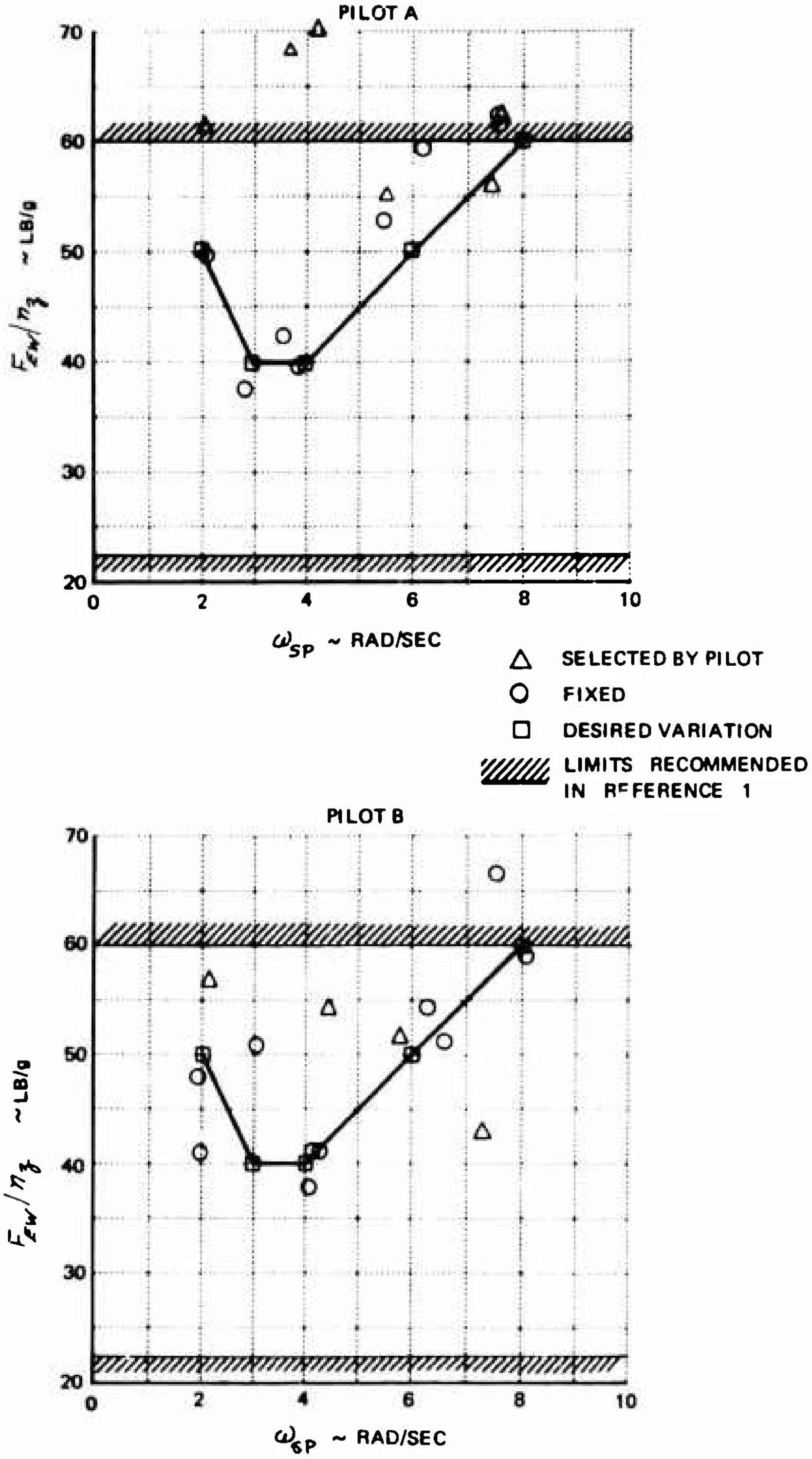


Figure 36 F_{EW}/n_z VS. ω_{SP} FOR GROUP I

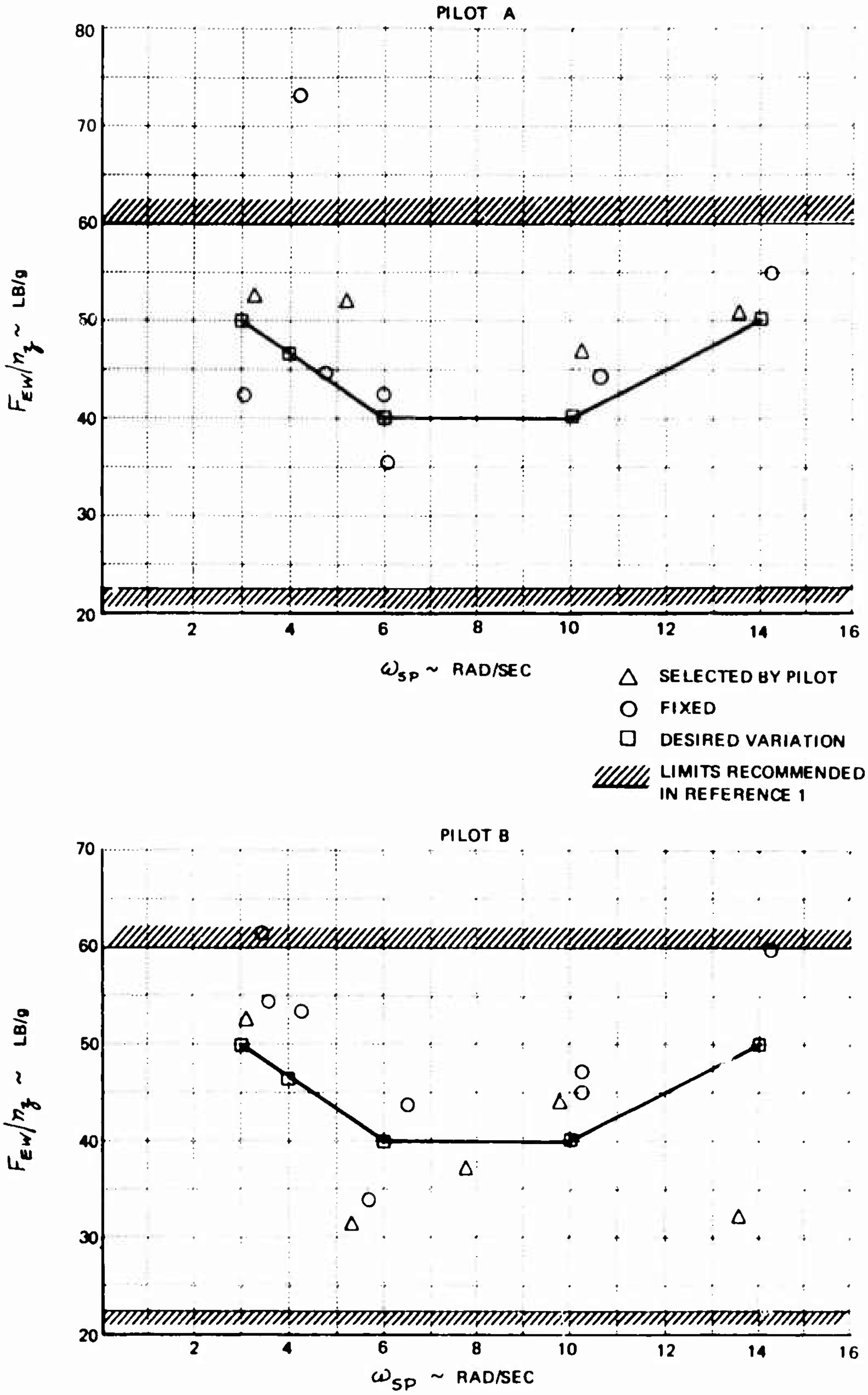


Figure 37 F_{EW} / n_z VS. ω_{SP} FOR GROUP II

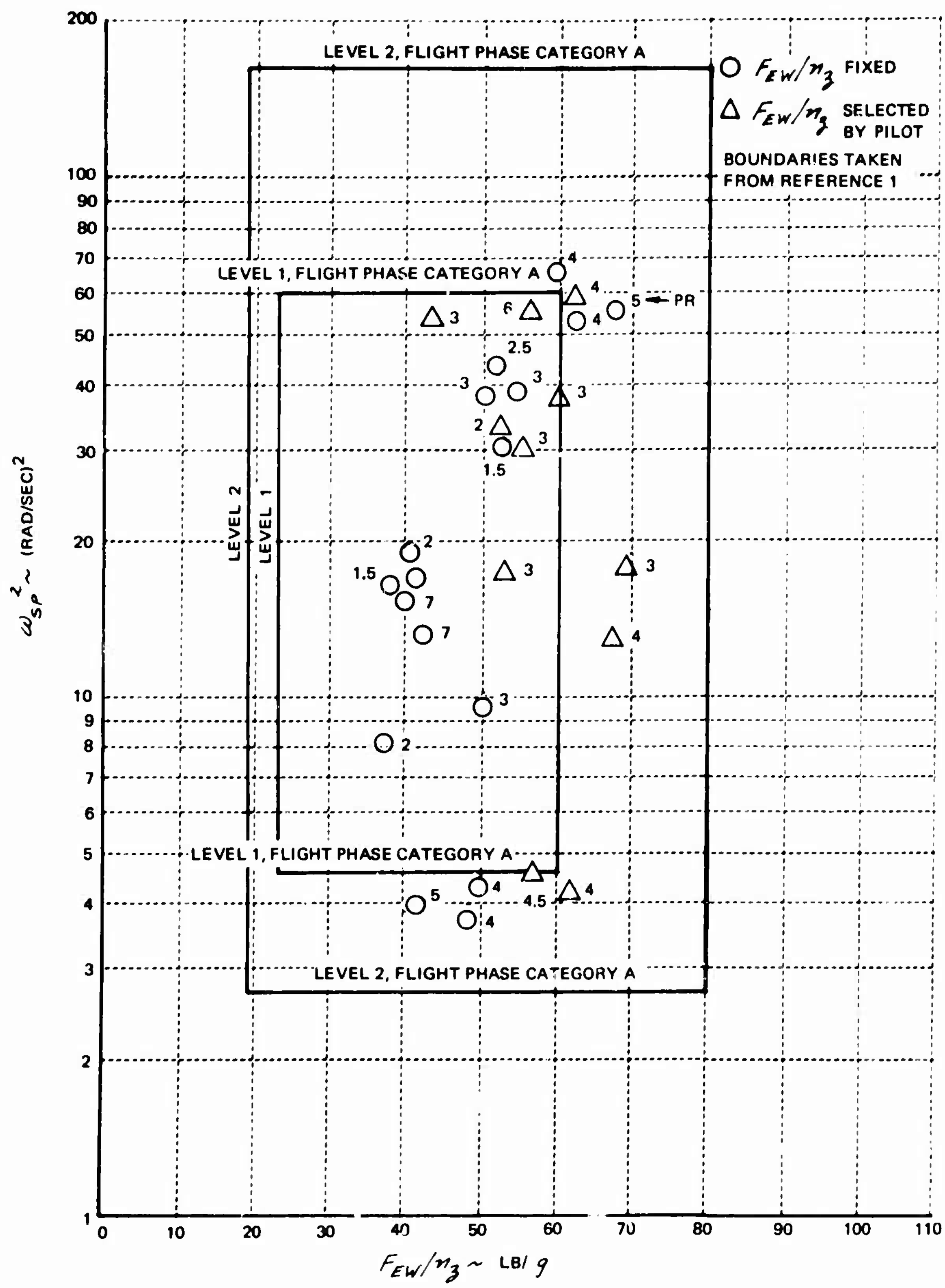


Figure 38 COMPARISON OF PILOT RATING DATA FOR BOTH PILOTS WITH PROPOSED MIL-F-8785 SPECIFICATION REQUIREMENTS FOR ω_{sp}^2 VS. F_{EW}/n_z (GROUP I)

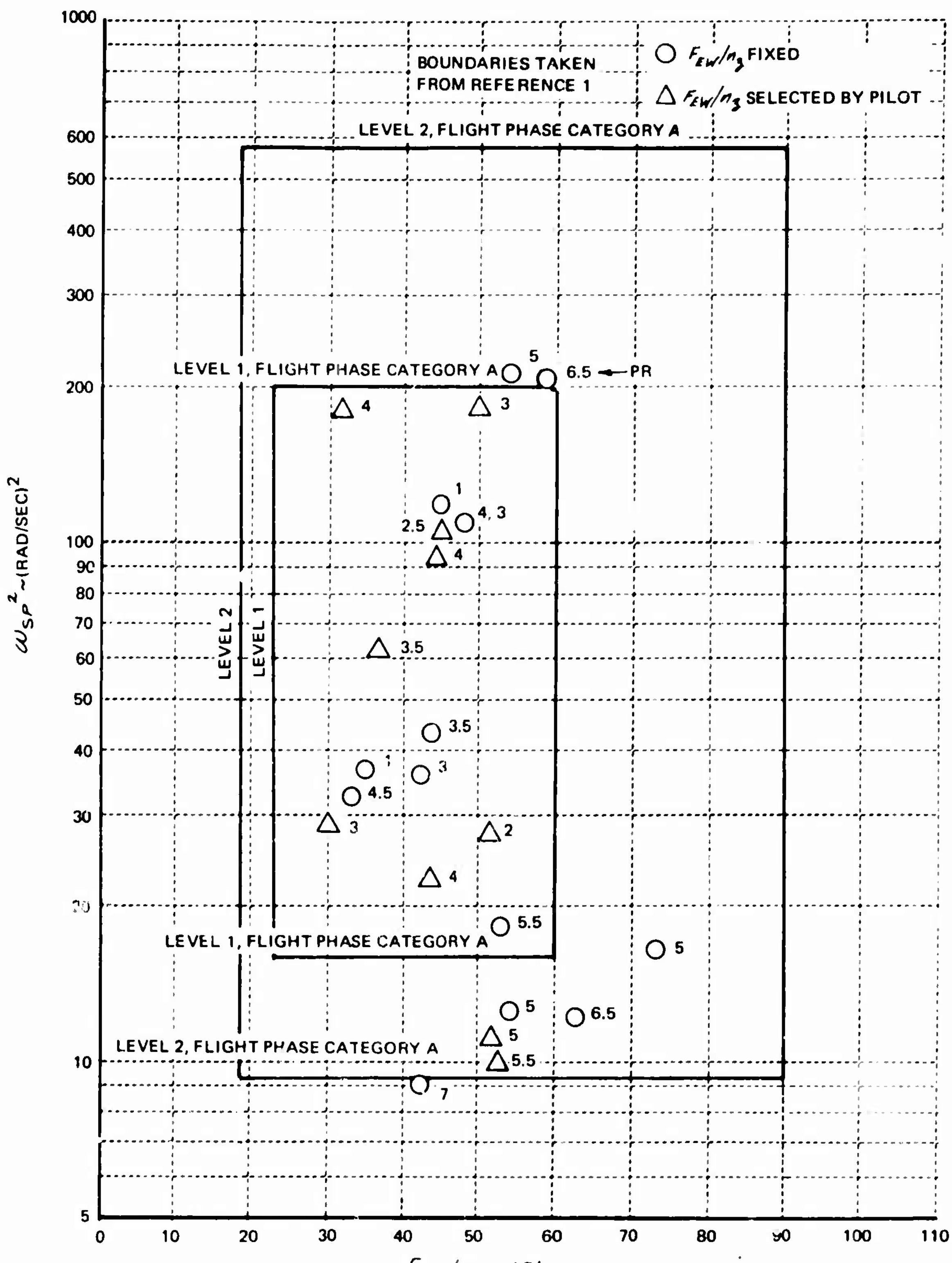


Figure 39 COMPARISON OF PILOT RATING DATA FOR BOTH PILOTS WITH PROPOSED MIL-F-8785 SPECIFICATION REQUIREMENTS FOR ω_{SP}^2 VS. F_{EW}/n_z (GROUP II)

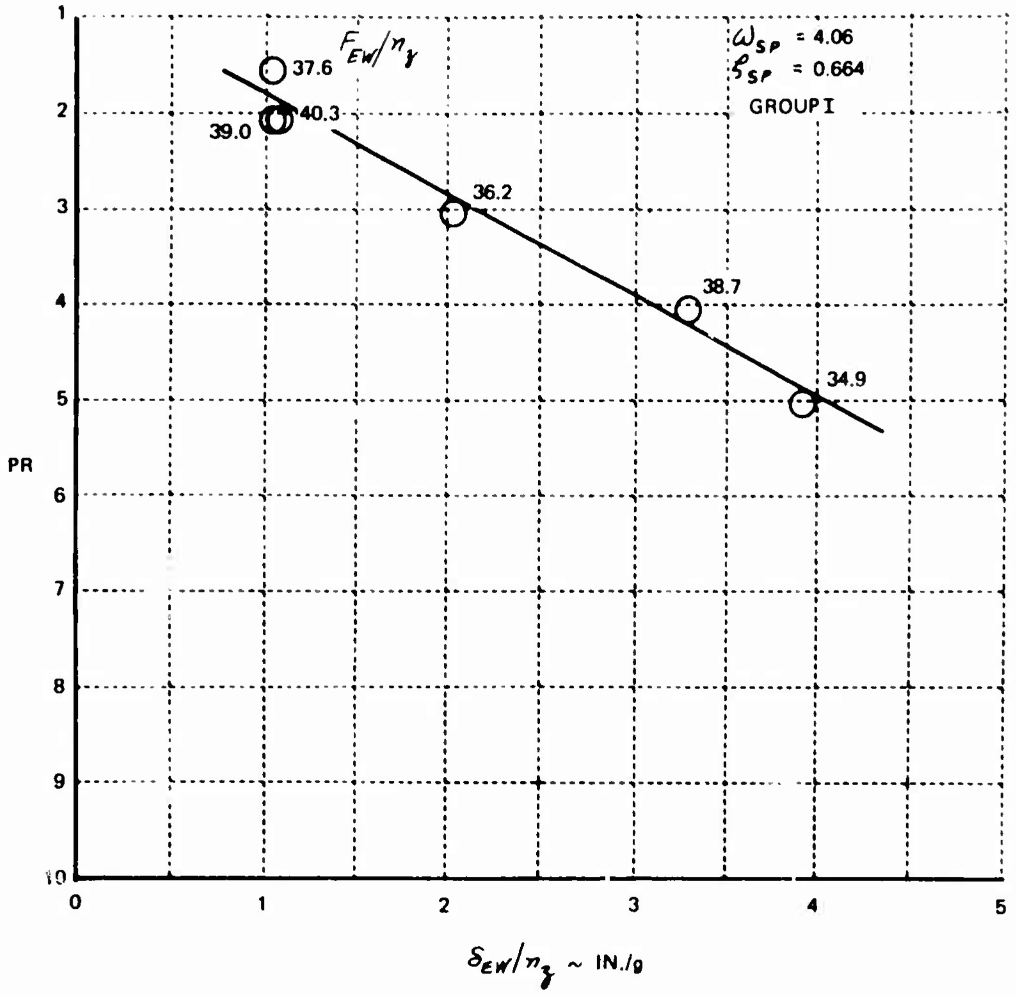


Figure 40 VARIATION IN PILOT RATING FOR δ_{EW}/n_z

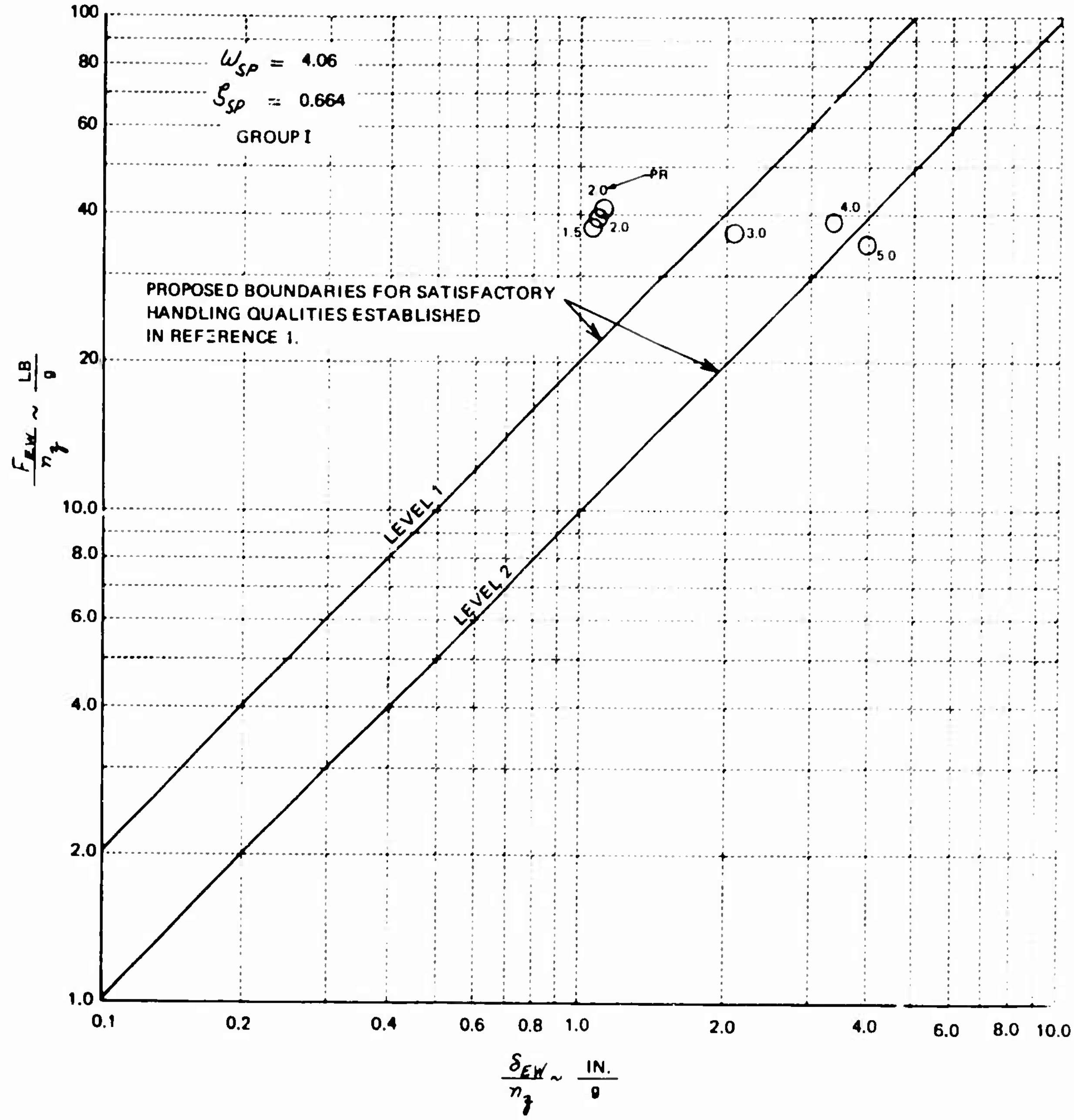


Figure 41 COMPARISON OF PILOT RATING DATA WITH PROPOSED MIL-F-8785 SPECIFICATION REQUIREMENTS FOR CHANGES IN δ_{EW}/n_z

Table I

PILOT COMMENT CARD

A. MAKE COMMENTS AT ANY TIME AS DESIRED.

B. MAKE GENERAL COMMENTS ON LONGITUDINAL HANDLING QUALITIES.

C. COMMENT ON THE FOLLOWING SPECIFIC ITEMS.

1. ABILITY TO TRIM - ANY DIFFICULTIES WITH AIRSPEED CONTROL?
2. FEEL SYSTEM CHARACTERISTICS-
   a. STICK FORCES
   b. STICK DISPLACEMENTS.
3. AIRPLANE RESPONSE TO PILOT INPUTS-
   a. INITIAL RESPONSE
   b. FINAL RESPONSE
4. PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL AND TRACKING CAPABILITY.
5. ALTITUDE CONTROL - ABILITY TO ACQUIRE AND STABILIZE ON A NEW ALTITUDE.
6. LONGITUDINAL CONTROL IN TURNS: ENTRY - MAINTAINING - RECOVERY.
7. CLIMBING AND DESCENDING TURNS.
8. COMMENT ON ATTITUDE TRACKING TASKS.
9. COMMENT ON CONTROL IN THE PRESENCE OF RANDOM DISTURBANCE.
10. WAS LATERAL-DIRECTIONAL CONTROL SATISFACTORY AND DID IT DETRACT FROM THE LONGITUDINAL EVALUATION?

D. SUMMARY COMMENTS ON OVERALL EVALUATION.

1. GOOD FEATURES.
2. OBJECTIONAL FEATURES.
3. SPECIAL PILOTING TECHNIQUES.
4. PIO RATING
5. PILOT RATING BASED ON MISSION PHASE-WORDS AND NUMBER
6. PRIMARY REASON FOR RATING.

Table II

PIO TENDENCY RATING SCALE

DESCRIPTION	NUMERICAL RATING
NO TENDENCY FOR PILOT TO INDUCE UNDESIRABLE MOTIONS.	1
UNDESIRABLE MOTIONS TEND TO OCCUR WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. THESE MOTIONS CAN BE PREVENTED OR ELIMINATED BY PILOT TECHNIQUE.	2
UNDESIRABLE MOTIONS EASILY INDUCED WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. THESE MOTIONS CAN BE PREVENTED OR ELIMINATED BUT ONLY AT SACRIFICE TO TASK PERFORMANCE OR THROUGH CONSIDERABLE PILOT ATTENTION AND EFFORT.	3
OSCILLATIONS TEND TO DEVELOP WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL PILOT MUST REDUCE GAIN OR ABANDON TASK TO RECOVER.	4
DIVERGENT OSCILLATIONS TEND TO DEVELOP WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. PILOT MUST OPEN LOOP BY RELEASING OR FREEZING THE STICK.	5
DISTURBANCE OR NORMAL PILOT CONTROL MAY CAUSE DIVERGENT OSCILLATION. PILOT MUST OPEN CONTROL LOOP BY RELEASING OR FREEZING THE STICK.	6

Table III

PILOT RATING SCALE

CONTROLLABLE Capable of being controlled or managed in context of mission with available pilot attention.	ACCEPTABLE May have deficiencies which warrant improvement, but adequate for mission. Pilot compensation, if required to achieve acceptable performance, is feasible.	SATISFACTORY Meets all requirements and expectations, good enough without improvement. Clearly adequate for mission	Excellent, highly desirable.	A1
			Good, pleasant, well behaved.	A2
			Fair. Some mildly unpleasant characteristics. Good enough for mission without improvement.	A3
		UNSATISFACTORY Reluctantly acceptable. Deficiencies which warrant improvement. Performance adequate for mission with feasible pilot compensation.	Some minor but annoying deficiencies. Improvement is requested. Effect on performance is easily compensated for by pilot.	A4
			Moderately objectionable deficiencies. Improvement is needed. Reasonable performance requires considerable pilot compensation.	A5
			Very objectionable deficiencies. Major improvements are needed. Requires best available pilot compensation to achieve acceptable performance.	A6
	UNACCEPTABLE Deficiencies which require mandatory improvement. Inadequate performance for mission even with maximum feasible pilot compensation.		Major deficiencies which require mandatory improvement for acceptance. Controllable. Performance inadequate for mission, or pilot compensation required for minimum acceptable performance in mission is too high.	U7
			Controllable with difficulty. Requires substantial pilot skill and attention to retain control and continue mission.	U8
			Marginally controllable in mission. Requires maximum available pilot skill and attention to retain control.	U9
UNCONTROLLABLE Control will be lost during some portion of the mission.			Uncontrollable in mission	10

APPENDIX I

LONGITUDINAL TRANSFER FUNCTIONS

The longitudinal equations of motion using the following assumptions:

1. Stability axes
2. Constant speed
3. Incremental effects of gravity are neglected

can be written as:

$$\ddot{\theta} = M_q\dot{\theta} + M_{\dot{\alpha}}\dot{\alpha} + M_\alpha \alpha + M_{\delta_e}\delta_e \tag{I-1}$$

$$\dot{\alpha} = \dot{\theta} - L_\alpha \alpha - L_{\delta_e}\delta_e \tag{I-2}$$

$$n_z = \frac{V_o}{g}(\dot{\theta} - \dot{\alpha}) \tag{I-3}$$

The following transfer functions in Laplace notation are written assuming the wings are always level so that $\dot{\theta} = s\theta = q$ and that the dependent variables θ, α and δ_e are incremental values from the reference condition:

$$\frac{\dot{\theta}(s)}{\delta_e(s)} = \frac{(M_{\delta_e} - L_{\delta_e}M_{\dot{\alpha}})s + (M_{\delta_e}L_\alpha - M_\alpha L_{\delta_e})}{s^2 + (L_\alpha - M_q - M_{\dot{\alpha}})s - (M_\alpha + M_q L_\alpha)} \tag{I-4}$$

$$\frac{\alpha(s)}{\delta_e(s)} = \frac{-L_{\delta_e}s + (M_{\delta_e} + M_q L_{\delta_e})}{s^2 + (L_\alpha - M_q - M_{\dot{\alpha}})s - (M_\alpha + M_q L_\alpha)} \tag{I-5}$$

$$\frac{n_z(s)}{\delta_e(s)} = \frac{V}{g}\,\frac{L_{\delta_e}s^2 + (-L_{\delta_e}M_q - L_{\delta_e}M_{\dot{\alpha}})s + (M_{\delta_e}L_\alpha - M_\alpha L_{\delta_e})}{s^2 + (L_\alpha - M_q - M_{\dot{\alpha}})s - (M_\alpha + M_q L_\alpha)} \tag{I-6}$$

Assuming that the product of small terms is negligible ($L_{\delta_e}M_q \approx L_{\delta_e}M_{\dot{\alpha}} \approx 0$)

$$\frac{\dot{\theta}(s)}{\delta_e(s)} = \frac{M_{\delta_e}\left(s + \left[\frac{M_{\delta_e}L_\alpha - M_\alpha L_{\delta_e}}{M_{\delta_e}}\right]\right)}{s^2 + (L_\alpha - M_q - M_{\dot{\alpha}})s - (M_\alpha + M_q L_\alpha)} \tag{I-7}$$

$$\frac{\alpha(s)}{\delta_e(s)} = \frac{M_{\delta_e}\left[-\frac{L_{\delta_e}}{M_{\delta_e}} s + 1\right]}{s^2 + (L_\alpha - M_q - M_{\dot\alpha})s - (M_\alpha + M_q L_\alpha)} \qquad \text{(I-8)}$$

$$\frac{n_z(s)}{\delta_e(s)} = \frac{V}{g} \frac{\left[M_{\delta_e} L_\alpha - M_\alpha L_{\delta_e}\right]\left[\frac{L_{\delta_e}}{M_{\delta_e} L_\alpha - M_\alpha L_{\delta_e}} s^2 + 1\right]}{s^2 + (L_\alpha - M_q - M_{\dot\alpha})s - (M_\alpha + M_q L_\alpha)} \qquad \text{(I-9)}$$

The short-period natural frequency and damping ratio can be expressed:

$$\omega_{sp}^2 = -M_\alpha - M_q L_\alpha \qquad \text{(I-10)}$$

$$2\zeta_{sp}\omega_{sp} = L_\alpha - M_q - M_{\dot\alpha} \qquad \text{(I-11)}$$

$$\zeta_{sp} = \frac{L_\alpha - M_q - M_{\dot\alpha}}{2\sqrt{-M_\alpha - M_q L_\alpha}} \qquad \text{(I-12)}$$

$$\frac{1}{T_{\theta_2}} = \frac{M_{\delta_e} L_\alpha - M_\alpha L_{\delta_e}}{M_{\delta_e}} \qquad \text{(I-13)}$$

$$\tau_\alpha = -\frac{L_{\delta_e}}{M_{\delta_e}} \qquad \text{(I-14)}$$

$$\tau_{n_z} = \pm\sqrt{\frac{L_{\delta_e}}{M_{\delta_e} L_\alpha - M_\alpha L_{\delta_e}}} \qquad \text{(I-15)}$$

Making these substitutions

$$\frac{\dot\theta(s)}{\delta_e(s)} = \frac{M_{\delta_e}\left(s + 1/T_{\theta_2}\right)}{s^2 + 2\zeta_{sp}\omega_{sp} s + \omega_{sp}^2} \qquad \text{(I-16)}$$

$$\frac{\alpha(s)}{\delta_e(s)} = \frac{M_{\delta_e}(\tau_\alpha s + 1)}{s^2 + 2\zeta_{sp}\omega_{sp} s + \omega_{sp}^2} \qquad \text{(I-17)}$$

$$\frac{n_z(s)}{\delta_e(s)} = \frac{V}{g}\frac{1}{T_{\theta_2}}\frac{M_{\delta_e}(\tau_{n_z} s + 1)(-\tau_{n_z} s + 1)}{s^2 + 2\zeta_{sp}\omega_{sp} s + \omega_{sp}^2} \qquad \text{(I-18)}$$

For almost all conventional airplanes, τ_α is quite small and can usually be neglected. τ_{n_z} is likewise negligible for most conventional airplanes, however, it increases in importance for airplanes on which L_{δ_e} is large and/or the tail length is quite short. In this experiment, the tail length was sufficient to make τ_{n_z} negligible. Thus assuming, $\tau_\alpha \approx \pm \tau_{n_z} \approx 0$ and making the above substitions, we have:

$$\frac{\dot{\theta}(s)}{\delta_e(s)} = \frac{M_{\delta_e}\left(s + 1/T_{\theta_2}\right)}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2} \tag{I-19}$$

$$\frac{\alpha(s)}{\delta_e(s)} = \frac{M_{\delta_e}}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2} \tag{I-20}$$

$$\frac{n_z(s)}{\delta_e(s)} = \frac{V}{g}\,\frac{1}{T_{\theta_2}}\,\frac{M_{\delta_e}}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2} \tag{I-21}$$

The following relationships are derived from the above transfer functions:

$$\frac{n_z(s)}{\alpha(s)} = \frac{n_z(s)/\delta_e(s)}{\alpha(s)/\delta_e(s)} = \frac{V}{g}\,\frac{1}{T_{\theta_2}} \tag{I-22}$$

$$\frac{n_z(s)}{\dot{\theta}(s)} = \frac{n_z(s)/\delta_e(s)}{\dot{\theta}(s)/\delta_e(s)} = \frac{V}{g}\,\frac{1}{T_{\theta_2}}\left|\frac{1}{s + 1/T_{\theta_2}}\right| \tag{I-23}$$

$$\frac{\ddot{\theta}(s)}{\delta_e(s)} = s\,\frac{\dot{\theta}(s)}{\delta_e(s)} = \frac{s M_{\delta_e}\left(s + 1/T_{\theta_2}\right)}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2} \tag{I-24}$$

The initial pitch acceleration, $\ddot{\theta}_0$, for a step elevator input can be obtained by the initial value theorem:

$$\frac{\ddot{\theta}_0}{\delta_e} = \lim_{s\to\infty}\left[s\left(\frac{\ddot{\theta}(s)}{s\delta_e(s)}\right)\right] = \lim_{s\to\infty}\left[\frac{M_{\delta_e}\left(1 + \frac{1}{T_{\theta_2}s}\right)}{1 + \frac{2\zeta_{sp}\omega_{sp}}{s} + \frac{\omega_{sp}^2}{s^2}}\right] \tag{I-25}$$

$$\frac{\ddot{\theta}_0}{\delta_e} = M_{\delta_e} \tag{I-26}$$

By the final value theorem, the steady state pitch rate to a step input is obtained:

$$\frac{\dot{\theta}_{ss}}{\delta_e} = \lim_{s \to 0}\left[s\left(\frac{\dot{\theta}(s)}{s\delta_e(s)}\right)\right] = \lim_{s \to 0}\left[\frac{M_{\delta_e}(s + 1/T_{\theta_2})}{s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2}\right] \tag{I-27}$$

$$\frac{\dot{\theta}_{ss}}{\delta_e} = \frac{M_{\delta_e}}{T_{\theta_2}\omega_{sp}^2} \tag{I-28}$$

The time history for the $\dot{\theta}$ response to a unit elevator step input (δ_e = 1) can be described as:

$$\dot{\theta}_{\delta_{e_{step}}} = \frac{M_{\delta_e}}{T_{\theta_2}\omega_{sp}^2} - \frac{M_{\delta_e}}{\omega_{sp}\sqrt{1-\zeta_{sp}^2}}\sqrt{\frac{\omega_{sp}^2(1-\zeta_{sp}^2)+(1/T_{\theta_2}-\zeta_{sp}\omega_{sp})^2}{\omega_{sp}^2}}\, e^{-\zeta_{sp}\omega_{sp}t} \sin\left(\omega_{sp}\sqrt{1-\zeta_{sp}^2}\,t + \psi_{\dot{\theta}_{sp}}\right) \tag{I-29}$$

where

$$\psi_{\dot{\theta}_{sp}} = \tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^2}}{\zeta_{sp}}\right) + \tan^{-1}\left(\frac{\omega_{sp}\sqrt{1-\zeta_{sp}^2}}{1/T_{\theta_2} - \zeta_{sp}\omega_{sp}}\right)$$

$$\ddot{\theta}_{\delta_{e_{step}}} = \frac{d\dot{\theta}}{dt} = \frac{M_{\delta_e}\zeta_{sp}}{\sqrt{1-\zeta_{sp}^2}}\sqrt{\omega_{sp}^2(1-\zeta_{sp}^2)+(1/T_{\theta_2}-\zeta_{sp}\omega_{sp})^2}\, e^{-\zeta_{sp}\omega_{sp}t} \sin\left(\omega_{sp}\sqrt{1-\zeta_{sp}^2}\,t + \psi_{\dot{\theta}_{sp}}\right)$$

$$-M_{\delta_e}\sqrt{\omega_{sp}^2(1-\zeta_{sp}^2)+(1/T_{\theta_2}-\omega_{sp}\zeta_{sp})^2}\, e^{-\zeta_{sp}\omega_{sp}t} \cos\left(\omega_{sp}\sqrt{1-\zeta_{sp}^2}\,t + \psi_{\dot{\theta}_{sp}}\right) \tag{I-30}$$

The time at which the maximum pitch rate overshoot, $\dot{\theta}_{MAX}$, will occur can be obtained from the conditions for $\ddot{\theta}$ = 0:

$$\sin\left(\omega_{sp}\sqrt{1-\zeta_{sp}^2}\,t + \psi_{\dot{\theta}_{sp}}\right) = \frac{\sqrt{1-\zeta_{sp}^2}}{\zeta_{sp}} \cos\left(\omega_{sp}\sqrt{1-\zeta_{sp}^2}\,t + \psi_{\dot{\theta}_{sp}}\right)$$

$$\tan\left(\omega_{sp}\sqrt{1-\zeta_{sp}^2}\,t + \psi_{\dot{\theta}_{sp}}\right) = \frac{\sqrt{1-\zeta_{sp}^2}}{\zeta_{sp}}$$

$$t = \frac{1}{\omega_{sp}\sqrt{1-\zeta_{sp}^{2}}}\left[\tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^{2}}}{\zeta_{sp}}\right) - \psi_{\dot{\theta}_{sp}}\right]$$

$$t = \frac{-1}{\omega_{sp}\sqrt{1-\zeta_{sp}^{2}}}\left[\tan^{-1}\left(\frac{\omega_{sp}\sqrt{1-\zeta_{sp}^{2}}}{1/T_{\theta_2} - \omega_{sp}\zeta_{sp}}\right)\right]$$

Thus we can define

$$\frac{\dot{\theta}_{MAX}}{\dot{\theta}_{ss}} = 1 - \frac{T_{\theta_2}}{\sqrt{1-\zeta_{sp}^{2}}}\sqrt{\omega_{sp}^{2}(1-\zeta_{sp}^{2}) + \left(1/T_{\theta_2} - \zeta_{sp}\omega_{sp}\right)^{2}}\; e^{\frac{\zeta_{sp}}{\sqrt{1-\zeta_{sp}^{2}}}\left[\tan^{-1}\left(\frac{\omega_{sp}\sqrt{1-\zeta_{sp}^{2}}}{1/T_{\theta_2} - \zeta_{sp}\omega_{sp}}\right)\right]} \sin\left[\tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^{2}}}{\zeta_{sp}}\right)\right] \quad \text{(I-31)}$$

which reduces to:

$$\frac{\dot{\theta}_{MAX}}{\dot{\theta}_{ss}} = 1 - \frac{1}{\sqrt{1-\zeta_{sp}^{2}}}\sqrt{1 - 2\zeta_{sp}\left(\omega_{sp}T_{\theta_2}\right) + \left(\omega_{sp}T_{\theta_2}\right)^{2}}\; e^{\frac{\zeta_{sp}}{\sqrt{1-\zeta_{sp}^{2}}}\left[\tan^{-1}\left(\frac{\omega_{sp}\sqrt{1-\zeta_{sp}^{2}}}{1/T_{\theta_2} - \zeta_{sp}\omega_{sp}}\right)\right]} \sin\left[\tan^{-1}\left(\frac{\sqrt{1-\zeta_{sp}^{2}}}{\zeta_{sp}}\right)\right] \quad \text{(I-32)}$$

APPENDIX II

CALCULATION OF $1/T_{\theta_2}$ AND n_3/α

The test program was designed primarily to evaluate the effect of n_3/α or $1/T_{\theta_2}$ on the short-period handling qualities requirements. In order to investigate as wide a range of n_3/α as possible, a low value of 16.5 g/rad and a high value of 56.2 g/rad were selected. The low value was determined primarily by the minimum speed at which the evaluation pilot could pull 2 g's without entering stall buffet. The high value was determined by the T-33's performance limitations.

The method used to minimize variations in n_3/α and $1/T_{\theta_2}$ for each configuration was based on the following analysis:

The equation for $1/T_{\theta_2}$ can be written as

$$\frac{1}{T_{\theta_2}} = \frac{g \rho V S}{2W} \left[C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}} \right] \qquad \text{(II-1)}$$

If we assume constant speed and neglect the incremental effects of gravity, then n_3/α can be approximated by:

$$\frac{n_3}{\alpha} = \frac{V}{g} \frac{1}{T_{\theta_2}} = \frac{\rho V^2 S}{2W} \left[C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}} \right] \qquad \text{(II-2)}$$

It can be seen that as the aircraft weight decreases due to fuel consumption, the velocity would have to be decreased proportionately to maintain a constant $1/T_{\theta_2}$. If a constant $1/T_{\theta_2}$ were maintained, then n_3/α would have to decrease. Thus, a compromise must be accepted wherein the variations of $1/T_{\theta_2}$ and n_3/α during an evaluation are held to a minimum.

Since $1/T_{\theta_2}$ varies directly with velocity and n_3/α varies directly with velocity squared, it was decided that $1/T_{\theta_2}$ should be the freer parameter. Based on the predicted aircraft weight change due to fuel consumption, two airspeeds for the low speed configurations (Group I) and two airspeeds for the high speed configurations (Group II) were chosen that would give an essentially constant mean n_3/α for both flight regimes. The program was designed to ensure that all the low speed configurations would be evaluated at aircraft gross weights between 15,400 lb and 13,270 lb, and all high speed configurations would be evaluated between 14,350 lb and 11,800 lb. The two airspeeds for the low speed configurations were then chosen to give a mean n_3/α of approximately 16.5 g/rad

and a mean $1/T_{\theta_2}$ of approximately 1.29 per sec. The airspeeds for the high speed configurations were selected to give a mean n_z/α of 56.2 g/rad and a mean $1/T_{\theta_2}$ of 2.65 per sec. The data upon which the selection of these airspeeds is based is presented in Figures II-1 and II-2. The actual airspeeds corresponding to the various gross weight ranges and the respective n_z/α 's and $1/T_{\theta_2}$'s are shown in Tables II-I and II-II.

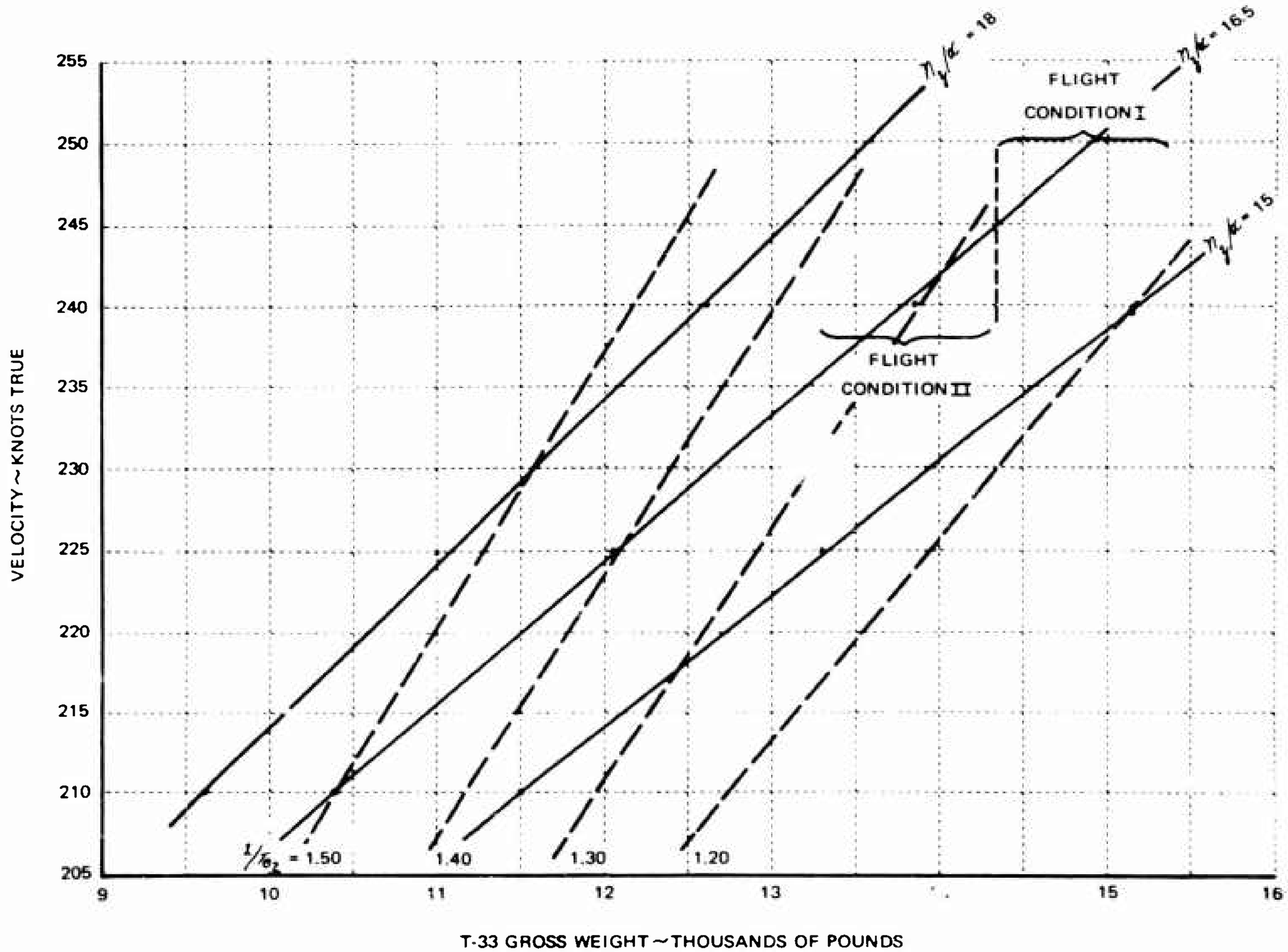


Figure II-1 $1/\tau_{\theta_2}$, n_z/α VS. VELOCITY AND GROSS WEIGHT FOR GROUP I

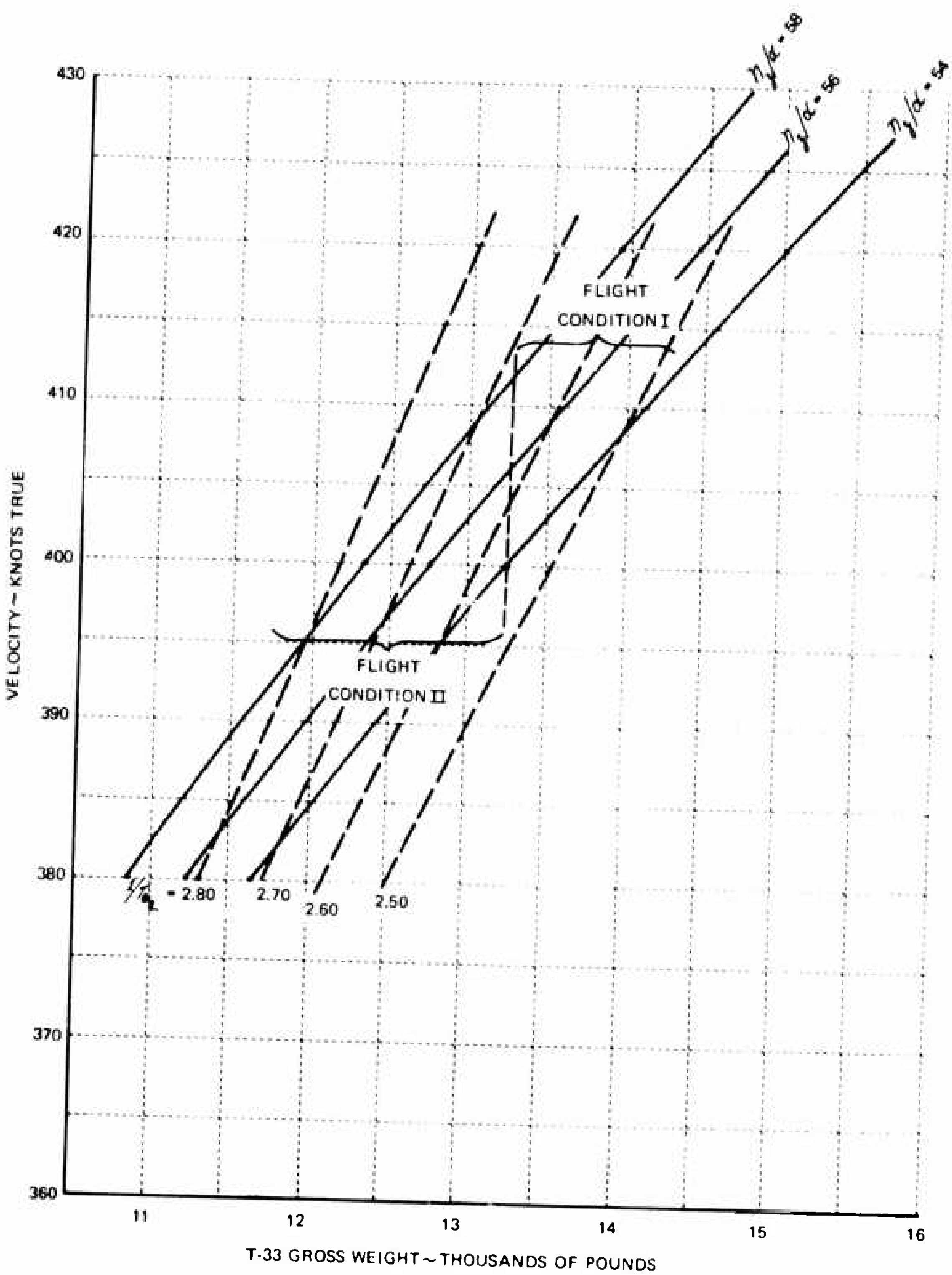


Figure II-2 $1/T_{\theta_2}$, n_z/α VS. VELOCITY AND GROSS WEIGHT FOR GROUP II

Table II-I

AIRSPEED SELECTION DATA

GROUP I

$$\frac{1}{T_{\theta_2}} = \frac{g}{V} \cdot \frac{n_z}{\alpha} \qquad W = 7.65\, T_{\theta_2} V \left[C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}} \right]$$

$n_z/\alpha = 15$	$n_z/\alpha = 16.5$	$n_z/\alpha = 18$
V_T = 210 KT = 355 FT/SEC, M = .324 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.76$ $\frac{1}{T_{\theta_2}} = \frac{32.2}{355} \times 15 = 1.36$ W = 11,500 LB	V_T = 210 KT = 355 FT/SEC, M = .324 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.76$ $\frac{1}{T_{\theta_2}} = 1.50$ W = 10,400 LB	V_T = 210 KT = 355 FT/SEC, M = .324 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.76$ $\frac{1}{T_{\theta_2}} = 1.63$ W = 9,600 LB
V_T = 255 KT = 380 FT/SEC, M = .347 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.80$ $\frac{1}{T_{\theta_2}} = \frac{32.2}{380} \times 15 = 1.27$ W = 13,300 LB	V_T = 225 KT = 380 FT/SEC, M = .347 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.80$ $\frac{1}{T_{\theta_2}} = 1.40$ W = 12,050 LB	V_T = 225 KT = 380 FT/SEC, M = .347 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.80$ $\frac{1}{T_{\theta_2}} = 1.53$ W = 11,000 LB
V_T = 240 KT = 405 FT/SEC, M = .370 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.84$ $\frac{1}{T_{\theta_2}} = \frac{32.2}{405} \times 15 = 1.19$ W = 15,200 LB	V_T = 240 KT = 405 FT/SEC, M = .370 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.84$ $\frac{1}{T_{\theta_2}} = 1.31$ W = 13,800 LB	V_T = 240 KT = 405 FT/SEC, M = .370 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 5.84$ $\frac{1}{T_{\theta_2}} = 1.43$ W = 12,650 LB

Table II-I (Cont)

GROUP II

$n_z/\alpha = 54$	$n_z/\alpha = 56$	$n_z/\alpha = 58$
V_T = 380 KT = 642 FT/SEC, M = .586 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.42$ $\frac{1}{T_{\theta_2}} = \frac{32.2}{642} \times 54 = 2.71$ W = 11,650 LB	V_T = 380 KT = 642 FT/SEC, M = .586 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.42$ $\frac{1}{T_{\theta_2}} = 2.81$ W = 11,250 LB	V_T = 380 KT = 642 FT/SEC, M = .586 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.42$ $\frac{1}{T_{\theta_2}} = 2.91$ W = 10,850 LB
V_T = 400 KT = 676 FT/SEC, M = .616 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.58$ $\frac{1}{T_{\theta_2}} = \frac{32.2}{676} \times 54 = 2.57$ W = 13,250 LB	V_T = 400 KT = 676 FT/SEC, M = .616 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.58$ $\frac{1}{T_{\theta_2}} = 2.67$ W = 12,750 LB	V_T = 400 KT = 676 FT/SEC, M = .616 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.58$ $\frac{1}{T_{\theta_2}} = 2.76$ W = 13,950 LB
V_T = 420 KT = 710 FT/SEC, M = .647 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.76$ $\frac{1}{T_{\theta_2}} = \frac{32.2}{710} \times 54 = 2.45$ W = 15,000 LB	V_T = 420 KT = 710 FT/SEC, M = .647 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.76$ $\frac{1}{T_{\theta_2}} = 2.54$ W = 14,450 LB	V_T = 420 KT = 710 FT/SEC, M = .647 $\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right) = 6.76$ $\frac{1}{T_{\theta_2}} = 2.63$ W = 13,950 LB

Table II-II

VARIATION IN $\frac{1}{T_{\theta_2}}$ AND n_z/α WITH AIRSPEED AND FUEL REMAINING

VELOCITY TRUE - KT	WT. CHANGE LB	n_z/α (RANGE VALUE)	$\frac{1}{T_{\theta_2}}$ (RANGE VALUE)	$\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right)$
249 M =.394	700 FR - 540 FR 15400 - 14350	(16.1 - 17.3)	(1.23 - 1.32)	5.87
238 M =.367	540 FR - 375 FR 14350 - 13270	(15.6 - 16.9)	(1.25 - 1.35)	5.83
MEAN VALUES		16.5	1.29	5.85

$$\frac{1}{T_{\theta_2}} = \frac{g}{V} \times \frac{n_z}{\alpha} = \frac{g\rho VS}{2W}\left(C_L - \frac{C_{L_{\delta_a}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right), \quad \frac{g\rho S}{2} \text{ @ } 5500' = \frac{(32.2)\ (.00202)\ (234.8)}{2} = 7.65$$

249 KT = 421 FT/SEC

$$\left(\frac{1}{T_{\theta_2}}\right)_1 = \frac{(7.65)\ (421)\ (5.87)}{15400} = 1.23 \qquad \left(\frac{1}{T_{\theta_2}}\right)_2 = \frac{(7.65)\ (421)\ (5.87)}{14350} = 1.32$$

$$\frac{n_z}{\alpha_1} = \left(\frac{1}{T_{\theta_2}}\right)_1 \left(\frac{V}{g}\right) = 16.1 \qquad \frac{n_z}{\alpha_2} = 17.3$$

238 KT = 402 FT/SEC

$$\left(\frac{1}{T_{\theta_2}}\right)_1 = \frac{(7.65)\ (402)\ (5.83)}{14350} = 1.25 \qquad \left(\frac{1}{T_{\theta_2}}\right)_2 = \frac{(7.65)\ (402)\ (5.83)}{13270} = 1.35$$

$$\frac{n_z}{\alpha_1} = 15.6 \qquad \frac{n_z}{\alpha_2} = 16.9$$

Table II-II (Cont.)

VARIATION IN $\frac{1}{T_{\theta_2}}$ AND n_z/α WITH AIRSPEED AND FUEL REMAINING

VELOCITY TRUE - KT	WT. CHANGE LB	n_z/α (RANGE VALUE)	$\frac{1}{T_{\theta_2}}$ (RANGE VALUE)	$\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right)$
413 M =.637	540 FR - 375 FR 14350 - 13270	(54.3 - 58.6)	(2.49 - 2.70)	6.70
396 M =.610	375 FR - 150 FR 13270 - 11790	(52.7 - 59.5)	(2.53 - 2.84)	6.55
MEAN VALUES		56.2	2.65	6.62

$$\frac{1}{T_{\theta_2}} = \frac{g}{V} \times \frac{n_z}{\alpha} = \frac{g\rho VS}{2W}\left(C_{L_\alpha} - \frac{C_{L_{\delta_e}} C_{m_\alpha}}{C_{m_{\delta_e}}}\right), \quad \frac{g\rho S}{2} \text{ @ } 5500' = \frac{(32.2)\ (.00202)\ (234.8)}{2} = 7.65$$

413 KT = 698 FT/SEC

$$\left(\frac{1}{T_{\theta_2}}\right) = \frac{(7.65)\ (698)\ (6.70)}{14350} = 2.49 \qquad \left(\frac{1}{T_{\theta_2}}\right) = \frac{(7.65)\ (698)\ (6.70)}{13270} = 2.69$$

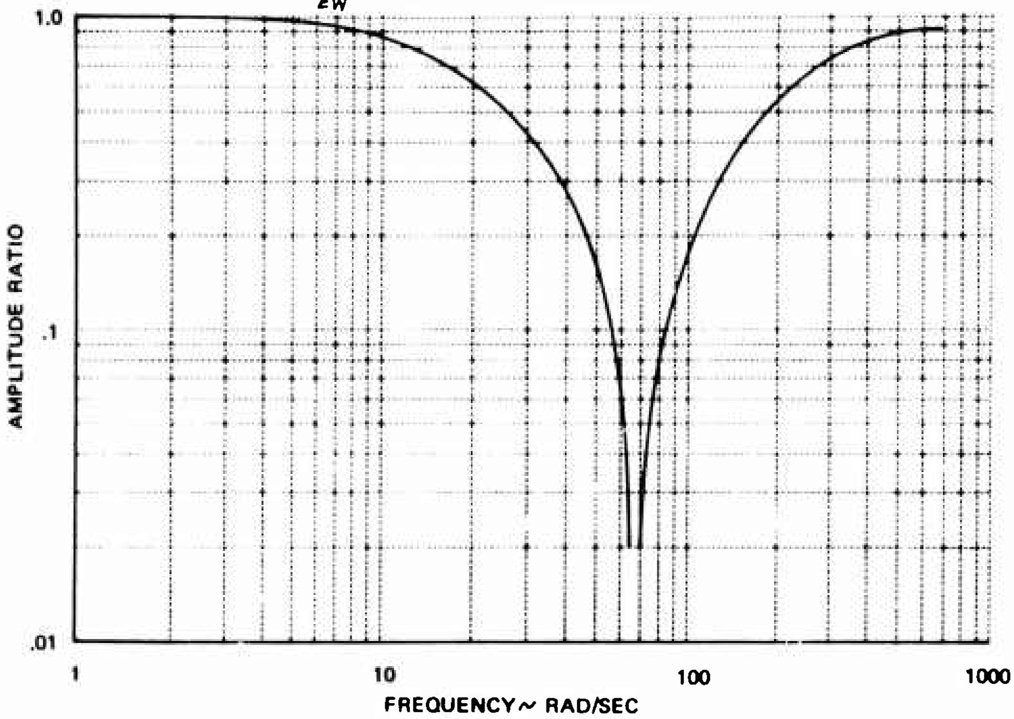
396 KT = 669 FT/SEC

$$\left(\frac{1}{T_{\theta_2}}\right) = \frac{(7.65)\ (669)\ (6.55)}{13270} = 2.53 \qquad \left(\frac{1}{T_{\theta_2}}\right) = \frac{(7.65)\ (669)\ (6.55)}{11790} = 2.84$$

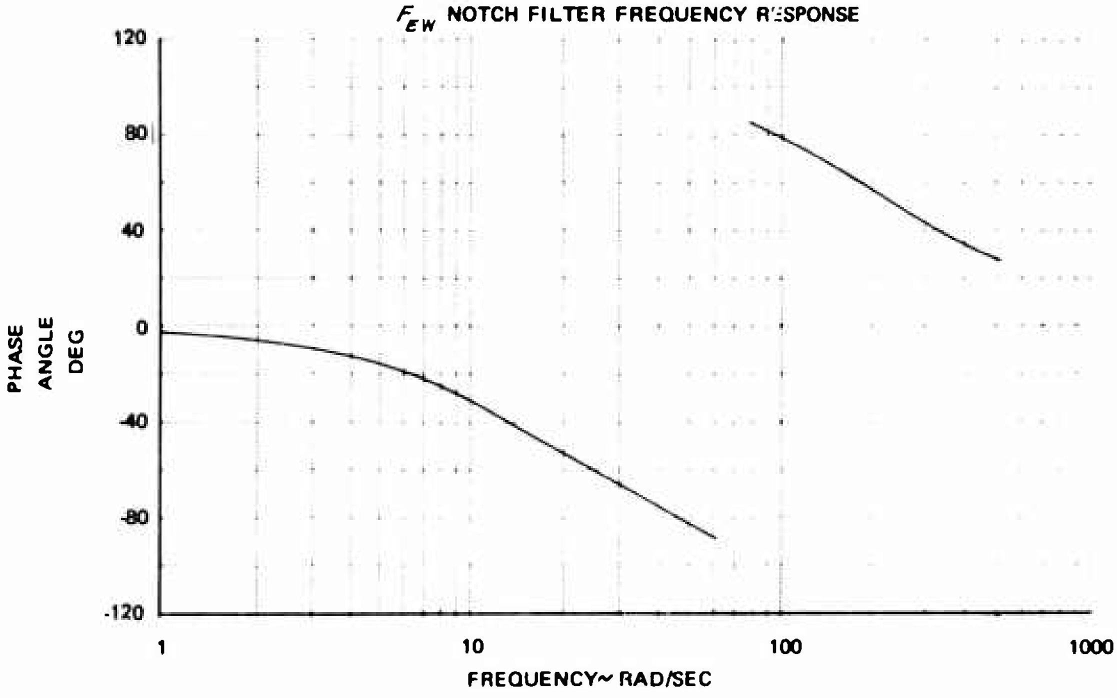
APPENDIX III

FEEL SYSTEM NOTCH FILTER CHARACTERISTICS

F_{EW} NOTCH FILTER FREQUENCY RESPONSE



F_{EW} NOTCH FILTER FREQUENCY RESPONSE



APPENDIX IV

CONFIGURATION IDENTIFICATION AND TIME HISTORIES

Table IV-I

SHORT-PERIOD HANDLING QUALITIES CONFIGURATIONS

PILOT A GROUP I

FLT NO.	ω_{sp} RAD/SEC	ζ_{sp}	n_z/α g/RAD	$1/T_{\theta_2}$ SEC^{-1}	F_{sw}/n_z LB/g	δ_{sw}/n_z IN/g	$2\zeta_{sp}\omega_{sp}$ RAD/SEC	$2\zeta_{sp}\omega_{sp}T_{\theta_2}$	ω_{sp}^2 (RAD/SEC)^2	CAP 1/SEC^2	$\omega_{sp}T_{\theta_2}$	$\phi_{\dot{\theta}_{sp}}$ DEG	PR	PIOR	SELECTED F_{sw}/n_z
893	2.05	0.71	15.4	1.23	61.2	1.11	2.93	2.39	4.20	0.27	1.67	143.8	4.0	1.0	YES
882	2.07	0.65	15.7	1.25	49.8	1.03	2.68	2.15	4.30	0.27	1.66	143.1	4.0	1.0	NO
884	2.85	0.60	15.7	1.25	37.8	0.98	3.42	2.73	8.10	0.52	2.28	154.5	2.0	1.0	NO
900	3.60	0.64	16.0	1.28	42.2	1.13	4.59	3.60	13.0	0.81	2.82	160.6	7.0	2.0	NO
900	3.61	0.68	16.4	1.30	67.2	1.01	4.95	3.79	13.0	0.79	2.77	160.7	4.0	2.0	YES
883	3.88	0.68	16.6	1.27	39.6	1.03	5.25	4.14	15.1	0.91	3.05	162.8	7.0	2.0	NO
881	≈4.0	≈0.7	≈16.1	≈1.23	39.8	1.03	TURBULENT	RECORDS				-	3.0	1.5	NO
894	4.24	0.66	16.5	1.31	69.9	1.25	5.61	4.27	18.0	1.09	3.23	163.7	3.0	1.5	YES
885	5.46	0.58	17.4	1.33	52.8	1.09	6.31	4.74	29.8	1.71	4.10	167.0	1.5	1.0	NO
896	5.52	0.57	17.1	1.31	55.2	1.06	6.35	4.67	30.5	1.78	4.22	166.8	3.0	1.5	YES
879	6.18	0.75	16.7	1.28	59.3	1.10	9.22	7.21	38.2	2.28	4.83	170.8	3.0	1.0	NO
895	7.45	0.67	17.5	1.34	55.9	1.88	10.06	7.50	55.5	3.16	5.55	171.4	6.0	3.0	YES
884	7.55	0.68	16.3	1.29	61.5	1.05	10.24	7.91	57.0	3.50	6.06	171.9	4.0	3.0	NO
887	7.55	0.66	17.7	1.36	61.9	1.15	9.91	7.03	57.0	3.21	5.58	170.9	4.0	2.0	NO
905	7.56	0.66	18.7	1.43	62.3	1.16	10.01	7.00	57.2	3.06	5.29	170.8	4.0	2.0	YES

PILOT B GROUP I

FLT NO.	ω_{sp} RAD/SEC	ζ_{sp}	n_z/α g/RAD	$1/T_{\theta_2}$ SEC^{-1}	F_{sw}/n_z LB/g	δ_{sw}/n_z IN/g	$2\zeta_{sp}\omega_{sp}$ RAD/SEC	$2\zeta_{sp}\omega_{sp}T_{\theta_2}$	ω_{sp}^2 (RAD/SEC)^2	CAP 1/SEC^2	$\omega_{sp}T_{\theta_2}$	$\phi_{\dot{\theta}_{sp}}$ DEG	PR	PIOR	SELECTED F_{sw}/n_z
897	1.97	0.69	15.8	1.26	47.9	1.00	2.72	2.17	3.80	0.24	1.56	140.3	4.0	3.0	NO
890	2.00	0.70	14.7	1.17	41.0	0.86	2.81	2.41	4.00	0.27	1.72	144.9	5.0	3.0	NO
899	2.12	0.60	17.4	1.33	56.4	1.06	2.55	1.92	4.50	0.26	1.59	141.2	4.5	2.0	YES
899	3.08	0.63	17.1	1.31	50.5	1.00	3.87	2.96	9.50	0.55	2.36	155.8	3.0	2.0	NO
888	4.05	0.6[illegible]	15.7	1.25	37.9	1.00	5.31	4.24	16.4	1.04	3.24	163.7	1.5	1.0	NO
904	4.15	0.65	15.9	1.27	41.1	1.05	5.37	4.21	17.2	1.08	3.28	163.8	2.0	2.0	NO
902	4.20	0.67	16.5	1.31	53.6	1.11	5.64	4.3	17.6	1.07	3.20	163.7	3.0	2.0	YES
891	4.30	0.61	15.6	1.24	41.1	1.10	5.29	4.28	18.5	1.19	3.48	164.6	2.0	1.5	NO
902	5.77	0.65	16.1	1.28	52.4	1.11	7.50	6.10	33.3	2.07	4.51	169.4	2.0	1.5	YES
886	6.28	0.66	16.4	1.31	54.1	1.19	8.33	6.38	39.4	2.40	4.81	169.8	3.0	2.0	NO
890	6.56	0.74	16.8	1.28	51.1	1.09	9.72	7.29	43.0	2.57	5.12	170.9	2.5	1.5	NO
901	7.25	0.66	18.4	1.41	43.0	0.99	9.51	6.77	52.6	2.85	5.16	170.5	3.0	2.0	YES
889	7.45	0.69	17.7	1.35	66.4	1.23	10.34	7.37	55.5	3.14	5.52	171.1	5.0	3.0	NO
891	8.00	0.69	15.1	1.20	59.0	0.90	11.07	9.24	64.0	4.24	6.67	173.1	4.0	1.5	NO

XXXX AIRPLANE + ELEVATOR ACTUATOR DYNAMICS
——— AIRPLANE + FEEL SYSTEM + ELEVATOR ACTUATOR DYNAMICS

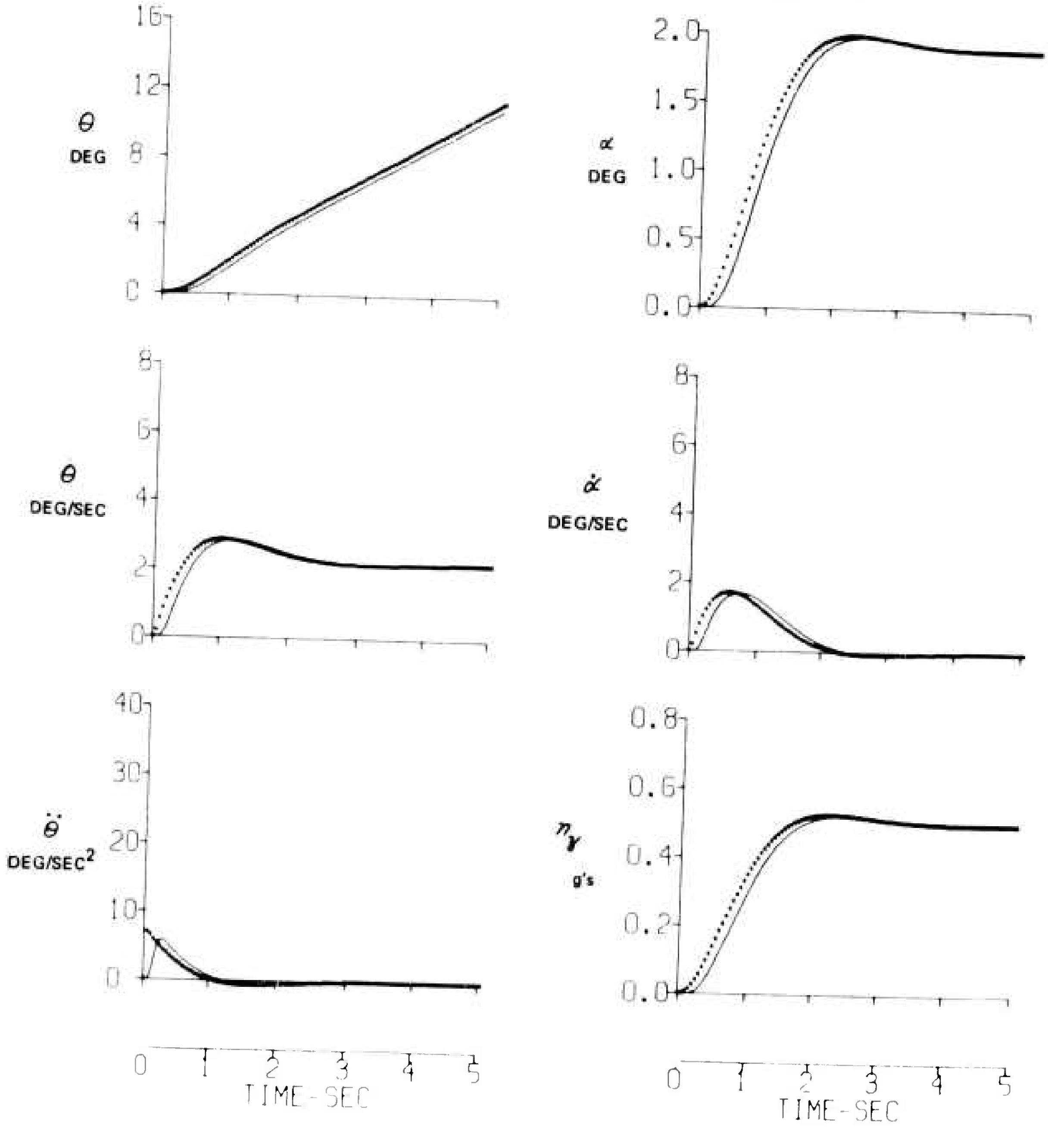


Figure IV-1 TIME HISTORY OF RESPONSE TO FLEVATOR STEP INPUT.
GROUP I, ω_{sp} = 1.96, ζ_{sp} = .694

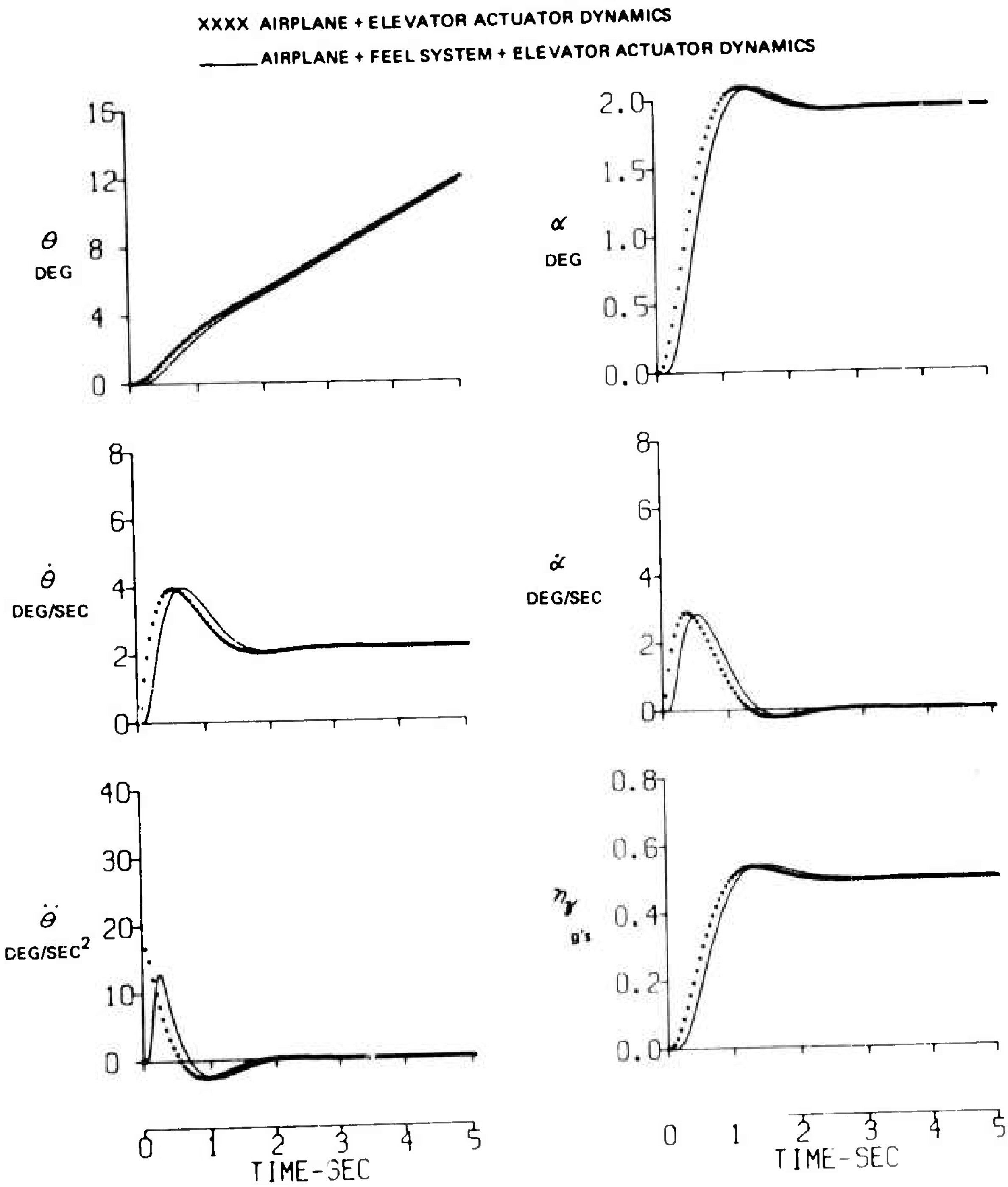


Figure IV-2 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP I, ω_{sp} = 3.08, ζ_{sp} = .628

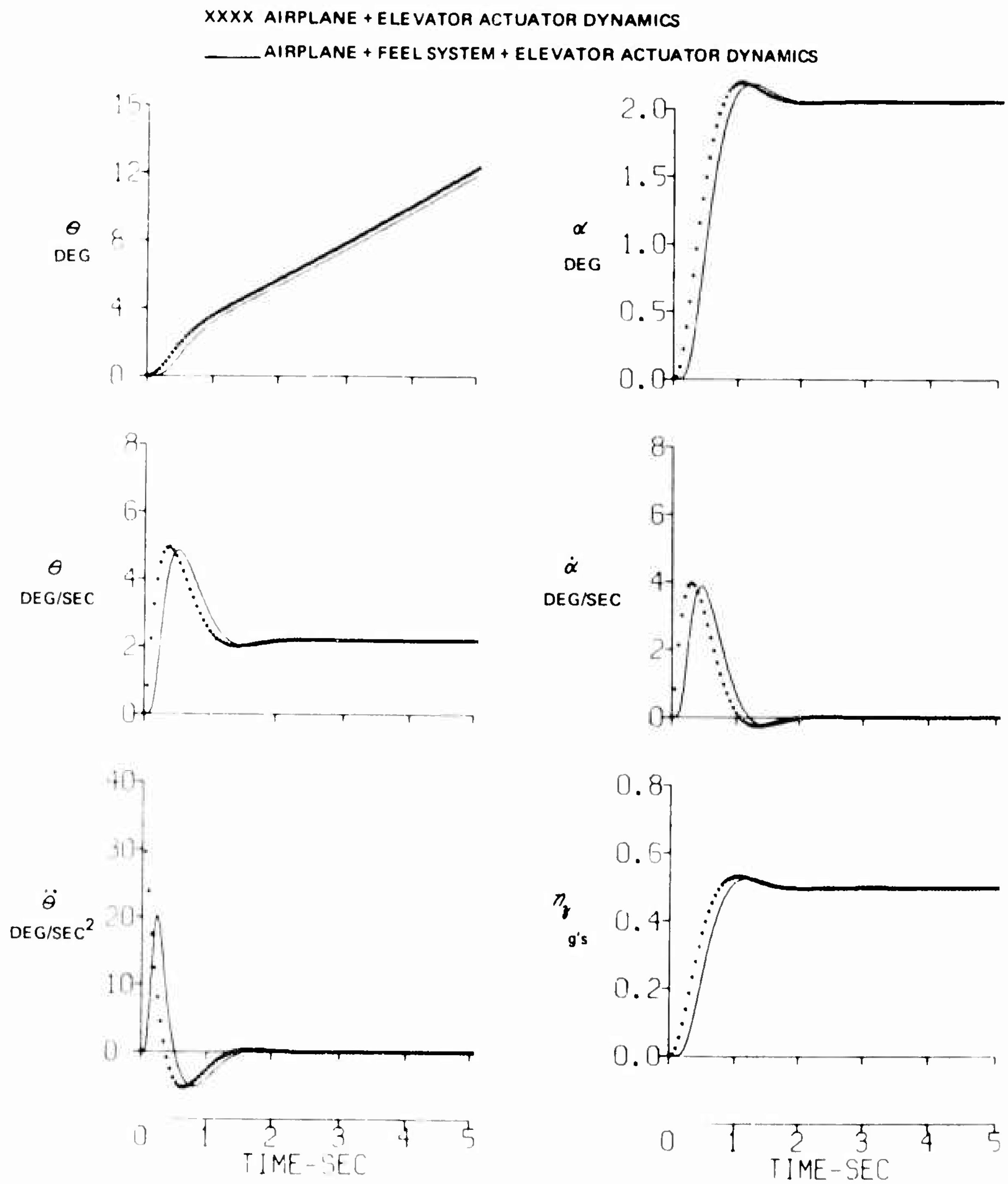


Figure IV-3 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP I, $\omega_{sp} = 4.05, \zeta_{sp} = .655$

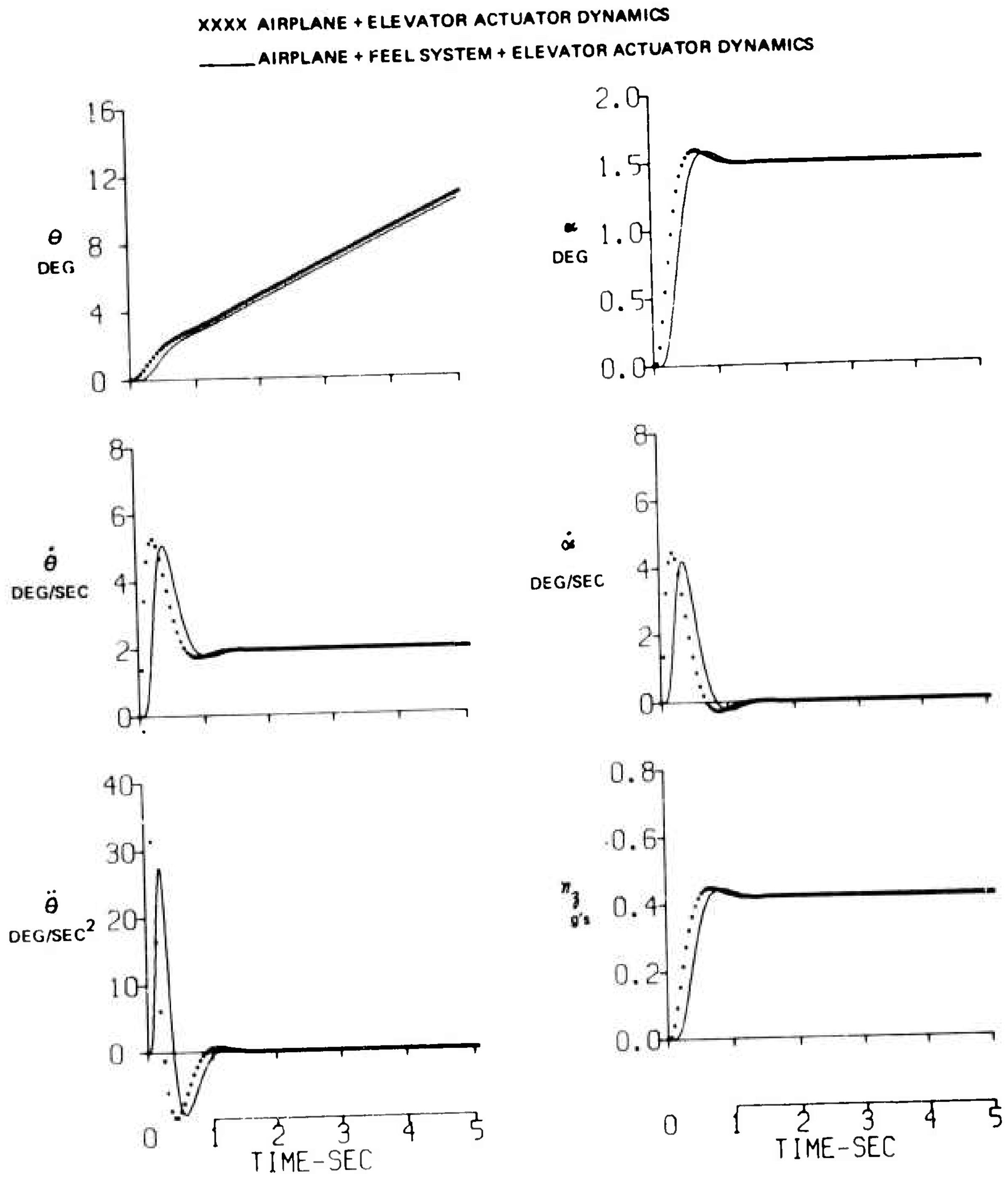


Figure IV-4 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP I, $\omega_{sp} = 6.28$, $\zeta_{sp} = .663$

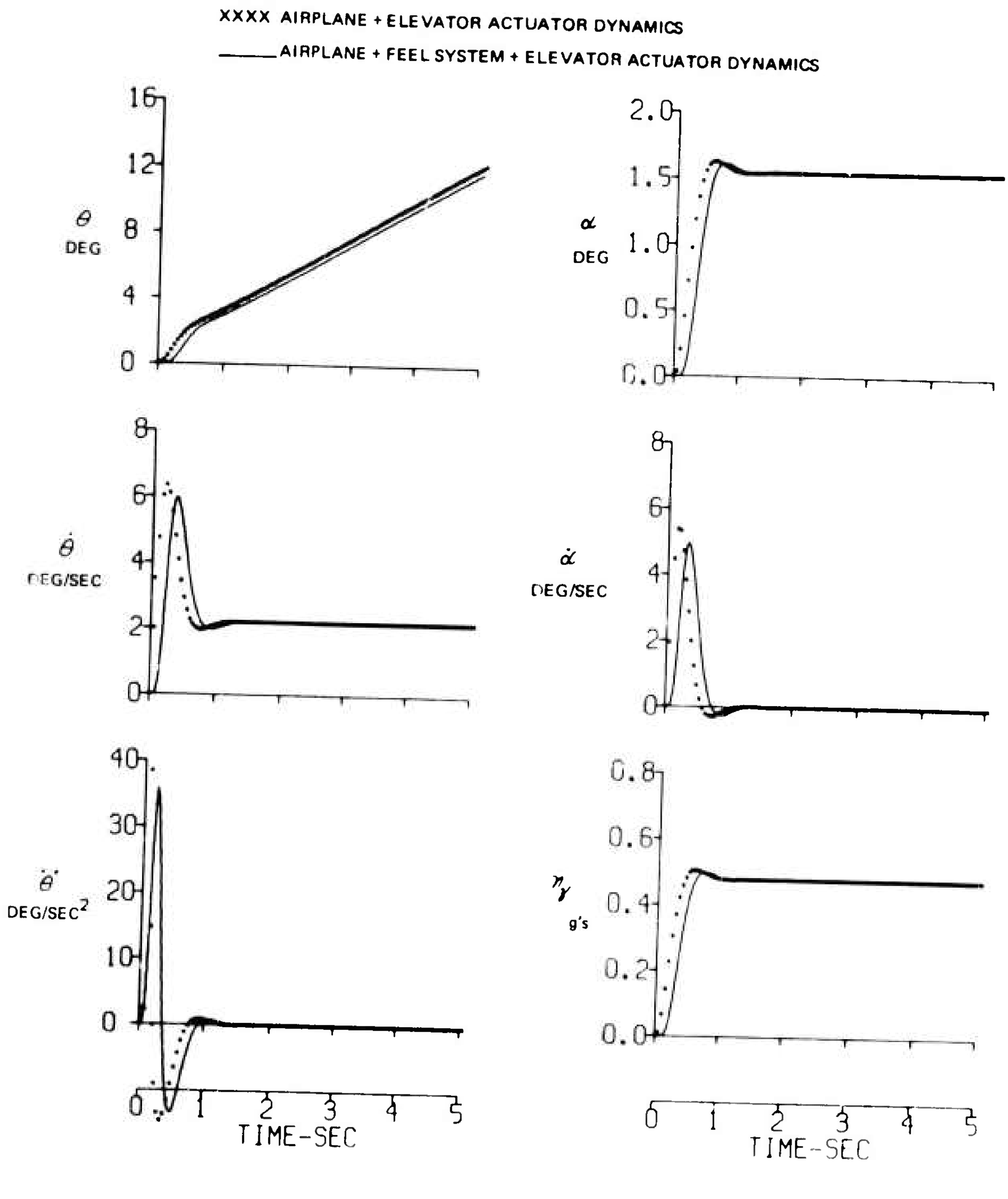


Figure IV-5 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP I, $\omega_{sp} = 7.55$, $\zeta_{sp} = .678$

Table IV-II
SHORT-PERIOD HANDLING QUALITIES CONFIGURATIONS

PILOT A GROUP II

FLT NO	ω_{SP} RAD/SEC	ζ_{SP}	n_z/α g/RAD	$1/T_{\theta_2}$ SEC^{-1}	F_{SW}/n_z LB/g	δ_{SW}/n_z IN/g	$2\zeta_{SP}\omega_{SP}$ RAD/SEC	$2\zeta_{SP}\omega_{SP}T_{\theta_2}$	ω_{SP}^2 (RAD/SEC)^2	CAP 1/SEC^2	$\omega_{SP}T_{\theta_2}$	$\phi_{\theta_{SP}}$ DEG	PR	PIOR	SELECTED F_{SW}/n_z
885	3.06	0.70	51.1	2.45	42.2	0.95	4.26	1.74	9.40	0.18	1.25	127.5	7.0	2.0	NO
905	3.33	0.60	56.8	2.62	52.1	1.45	3.98	1.52	11.1	0.19	1.27	130.1	5.0	1.5	YES
893	4.11	0.83	57.6	2.66	72.9	1.71	6.85	2.58	16.9	0.29	1.55	142.2	5.0	1.0	NO
900	4.76	0.53	58.8	2.71	44.4	1.16	5.03	1.85	22.7	0.38	1.75	145.3	4.0	1.5	YES
896	5.18	0.54	54.6	2.63	51.7	1.17	5.55	2.12	26.8	0.49	1.97	151.0	2.0	1.0	YES
884	5.98	0.60	61.7	2.85	42.3	1.08	7.18	2.52	35.8	0.58	2.10	151.9	3.0	1.0	NO
883	6.04	0.57	61.9	2.86	35.3	0.90	6.90	2.42	36.5	0.59	2.12	152.0	1.0	1.0	NO
895	10.20	0.66	55.0	2.04	46.5	1.21	13.40	5.07	104.0	1.89	3.86	166.8	2.5	1.0	YES
887	10.[illegible]0	0.72	60.7	2.80	44.3	1.16	15.18	5.42	112.4	1.85	3.79	167.2	1.0	1.0	NO
894	13.50	0.73	57.8	2.67	50.2	1.31	19.84	7.44	182.2	3.15	5.06	171.1	3.0	1.0	YES
885	14.20	0.65	57.5	2.65	54.7	1.20	18.43	6.95	201.6	3.51	5.35	170.8	5.0	1.0	NO

PILOT B GROUP II

FLT NO.	ω_{SP} RAD/SEC	ζ_{SP}	n_z/α g/RAD	$1/T_{\theta_2}$ SEC^{-1}	F_{SW}/n_z LB/g	δ_{SW}/n_z IN/g	$2\zeta_{SP}\omega_{SP}$ RAD/SEC	$2\zeta_{SP}\omega_{SP}T_{\theta_2}$	ω_{SP}^2 (RAD/SEC)^2	CAP 1/SEC^2	$\omega_{SP}T_{\theta_2}$	$\phi_{\theta_{SP}}$ DEG	PR	PIOR	SELECTED F_{SW}/n_z
901	3.16	0.62	51.2	2.46	52.3	1.67	3.89	1.53	10.0	0.19	1.28	130.3	5.5	2.0	YES
891	3.50	0.61	51.3	2.47	62.9	1.47	4.27	1.73	12.2	0.24	1.42	135.6	6.5	1.5	NO
886	3.64	0.83	54.9	2.64	54.4	1.22	6.04	2.29	13.2	0.24	1.38	134.6	5.0	2.0	NO
890	4.30	0.69	59.5	2.74	53.3	1.19	5.93	2.16	18.5	0.31	1.58	140.5	5.5	1.0	NO
899	5.34	0.55	54.0	2.60	30.1	1.00	5.85	2.26	28.5	0.53	2.06	151.0	3.0	1.5	YES
888	5.70	0.54	60.0	2.77	33.9	0.90	6.21	2.24	32.5	0.54	2.06	151.0	4.5	1.0	NO
897	6.50	0.53	58.2	2.69	43.8	1.13	6.95	2.59	42.2	0.73	2.42	155.9	3.5	2.0	NO
904	7.80	0.73	58.2	2.69	37.1	1.05	11.47	4.27	60.8	1.04	2.90	162.7	3.5	1.5	YES
902	9.80	0.77	55.2	2.65	44.1	1.19	15.19	5.73	96.0	1.74	3.70	167.8	4.0	2.0	YES
888	10.20	0.59	61.8	2.85	47.0	1.19	12.08	4.23	104.0	1.68	3.58	164.9	4.0	2.0	NO
897	10.20	0.67	59.1	2.73	45.0	1.16	13.71	5.03	104.0	1.76	3.74	166.4	3.0	1.5	NO
904	13.50	0.65	58.2	2.69	32.3	1.07	17.58	6.75	182.2	3.13	5.03	170.2	4.0	2.5	YES
889	14.20	0.70	58.7	2.71	59.6	1.26	19.88	7.35	201.6	3.44	5.25	171.1	6.5	-	NO

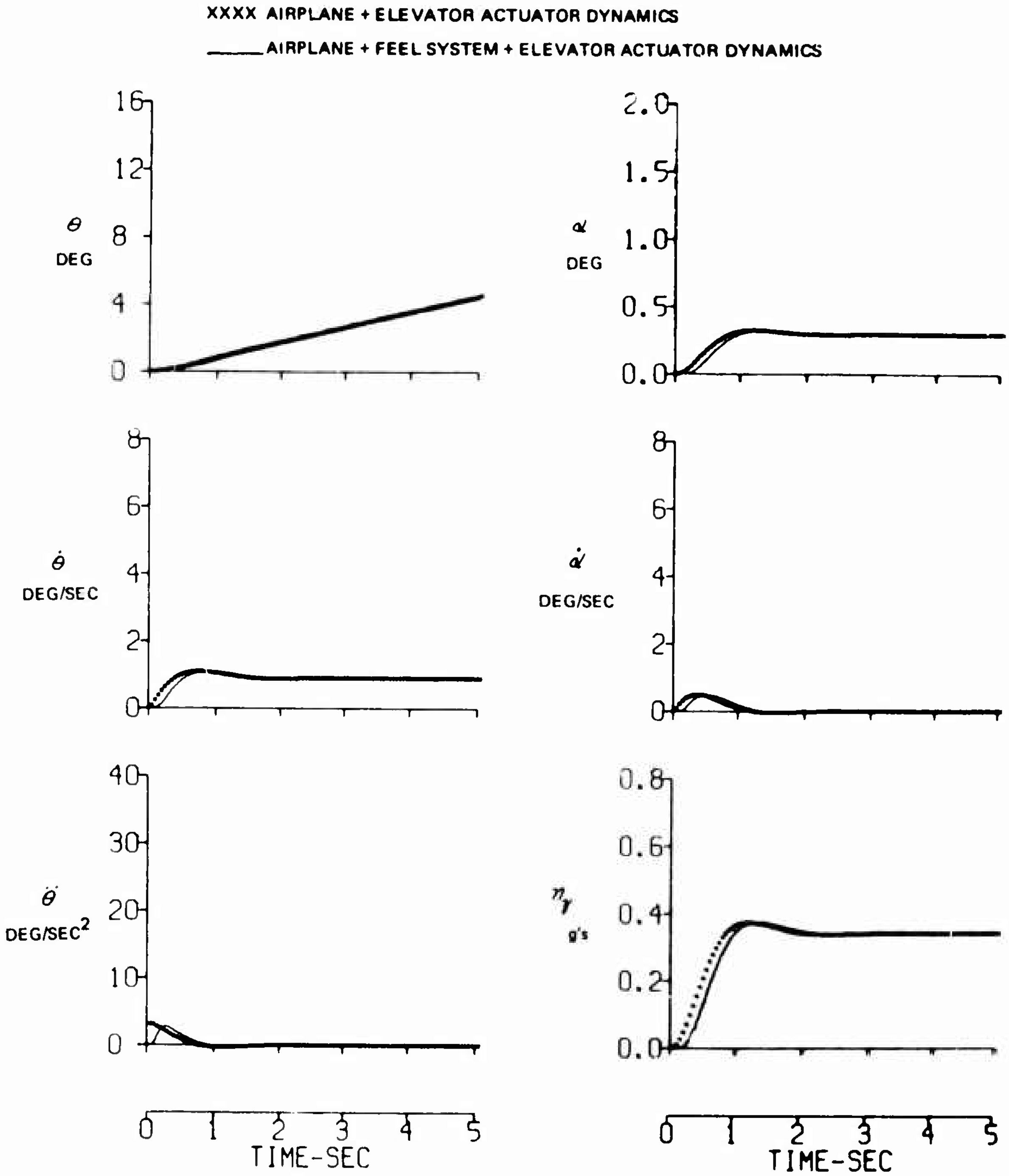


Figure IV-6 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP II, ω_{sp} = 3.33, ζ_{sp} = .598

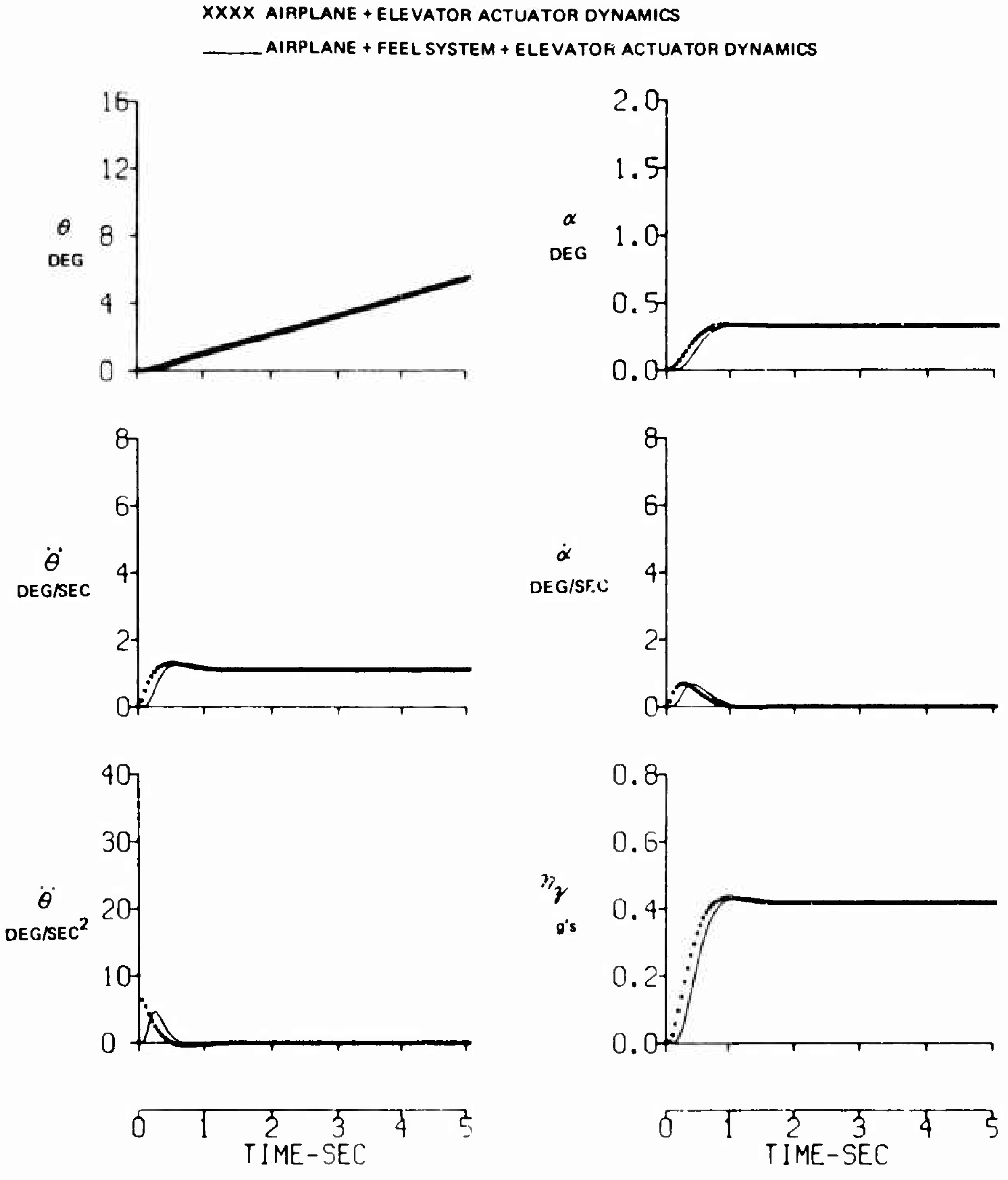


Figure IV-7 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP II, $\omega_{sp} = 4.70$, $\zeta_{sp} = .735$

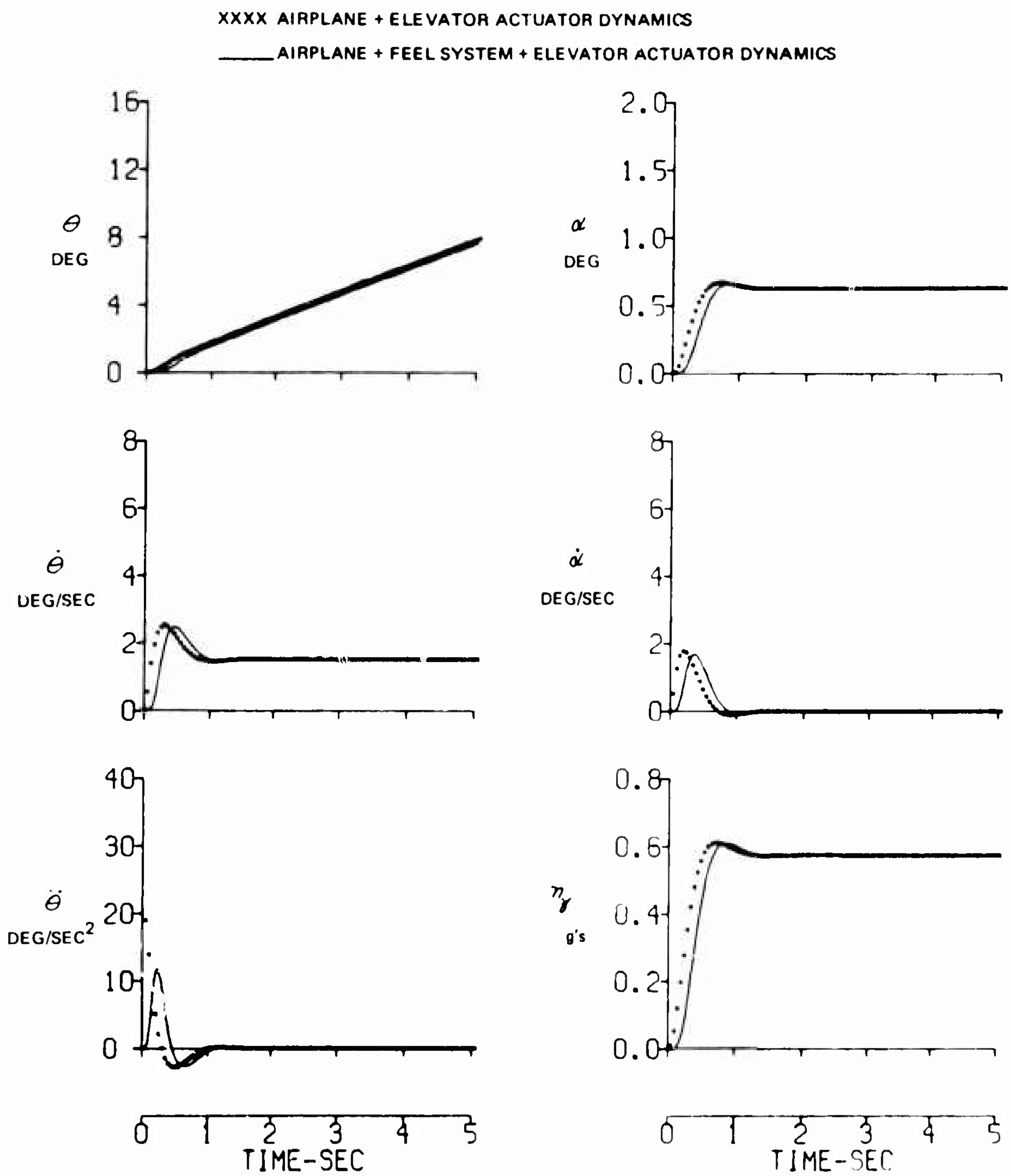


Figure IV-8 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP II, $\omega_{sp} = 5.96$, $\zeta_{sp} = .662$

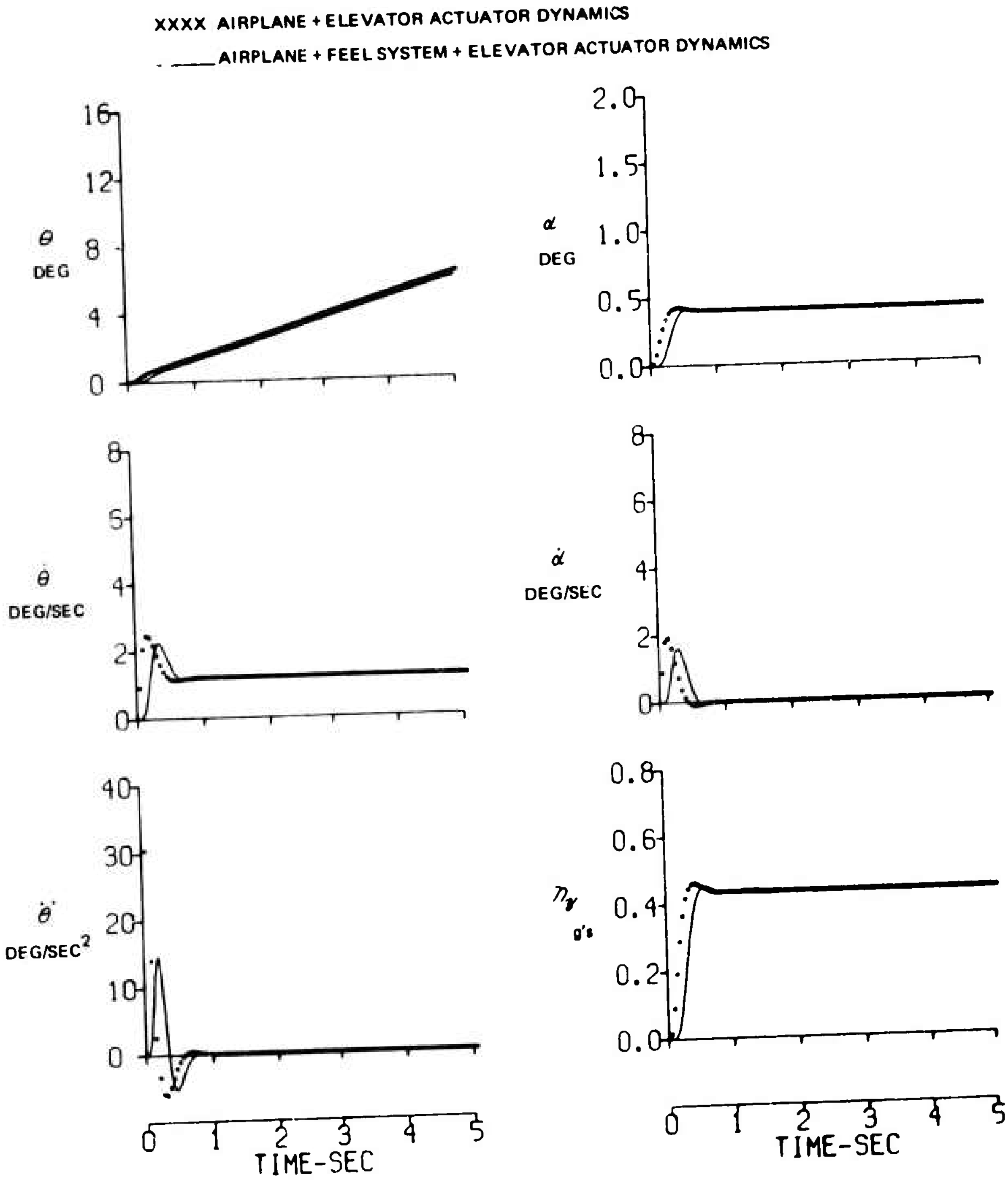


Figure IV-9 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP II, ω_{sp} = 10.20, ζ_{sp} = .672

XXXX AIRPLANE + ELEVATOR ACTUATOR DYNAMICS

——— AIRPLANE + FEEL SYSTEM + ELEVATOR ACTUATOR DYNAMICS

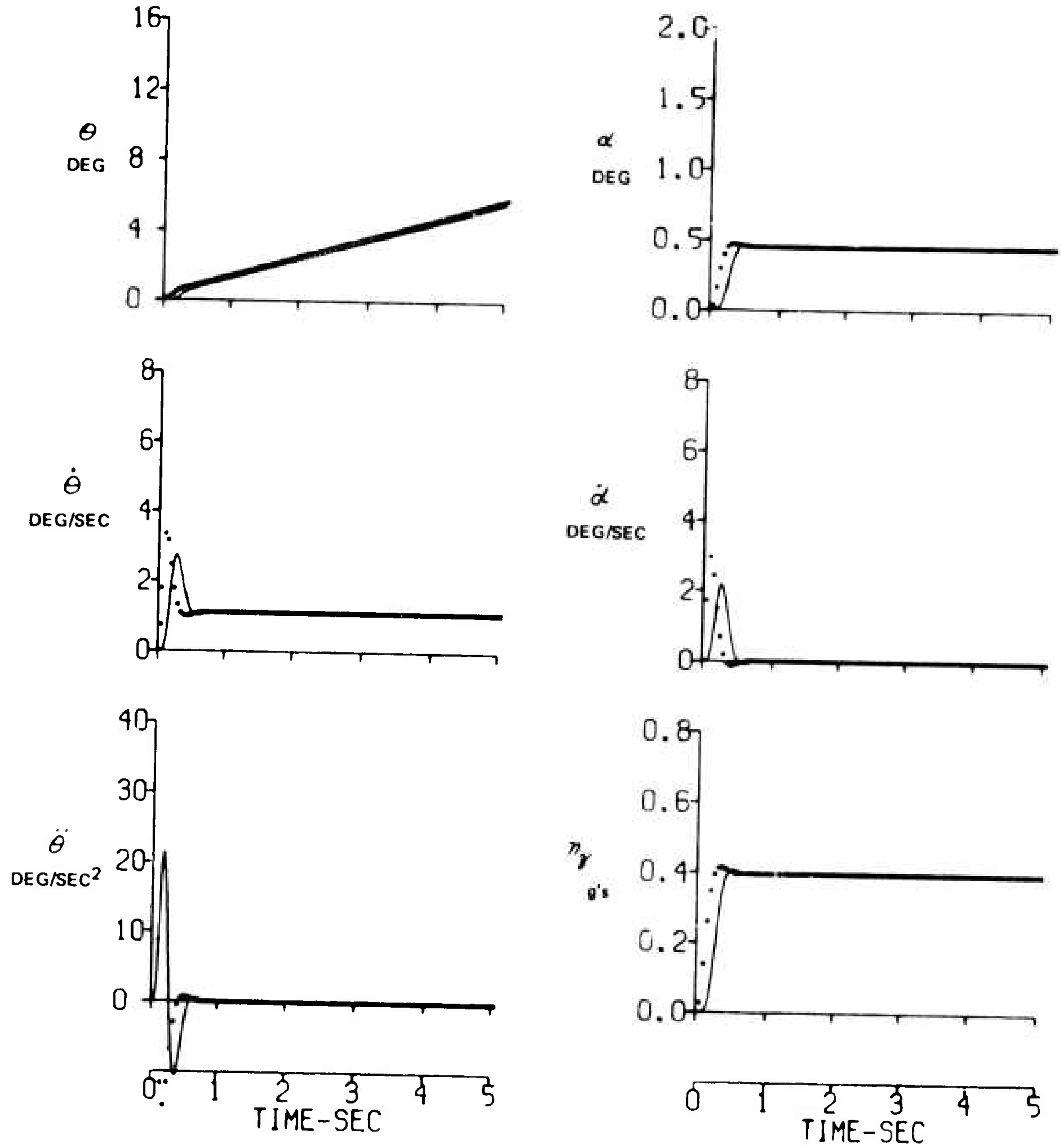


Figure IV-10 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT GROUP II, ω_{sp} = 14.20, ζ_{sp} = .70

Table IV-III
PIO INVESTIGATION CONFIGURATIONS

FLT	$1/T_{\theta_2}$	ω_{SP}	ζ_{SP}	$2\zeta_{SP}\omega_{SP}T_{\theta_2}$	$\frac{F_{EW}}{n_z}$	PR	PIOR	SELECTED F_{EW}/n_z
898	1.29	1.96	.077	.234	41.0	7	4	No
898	↓	1.96	.077	.234	70.0	6	4	Yes
906		no oscillograph record ≈ 4.0	≈ .1	≈ .620	≈40.0	7	2	No
906		no oscillograph record ≈ 4.0	≈ .1	≈ .620	≈60.0	5	-	Yes
908		4.02	.1	.624	48.0	7	2.5	No
908		4.02	.1	.624	93.5	4	-	Yes
907		6.09	.1	.944	67.0	7	4	No
907	↓	6.09	.1	.944	53.4	7	4	Yes
908	2.65	3.40	.11	.282	139.0	7	1.5	No
906		no oscillograph record ≈ 6.0	≈ .1	≈ .453	≈40.0	7	3.5	No
906		no oscillograph record ≈ 6.0	≈ .1	≈ .453	≈40.0	7	3.5	Yes
907		10.3	.11	.855	59.0	7	4	No
907	↓	10.3	.11	.855	40.0	7	4	Yes

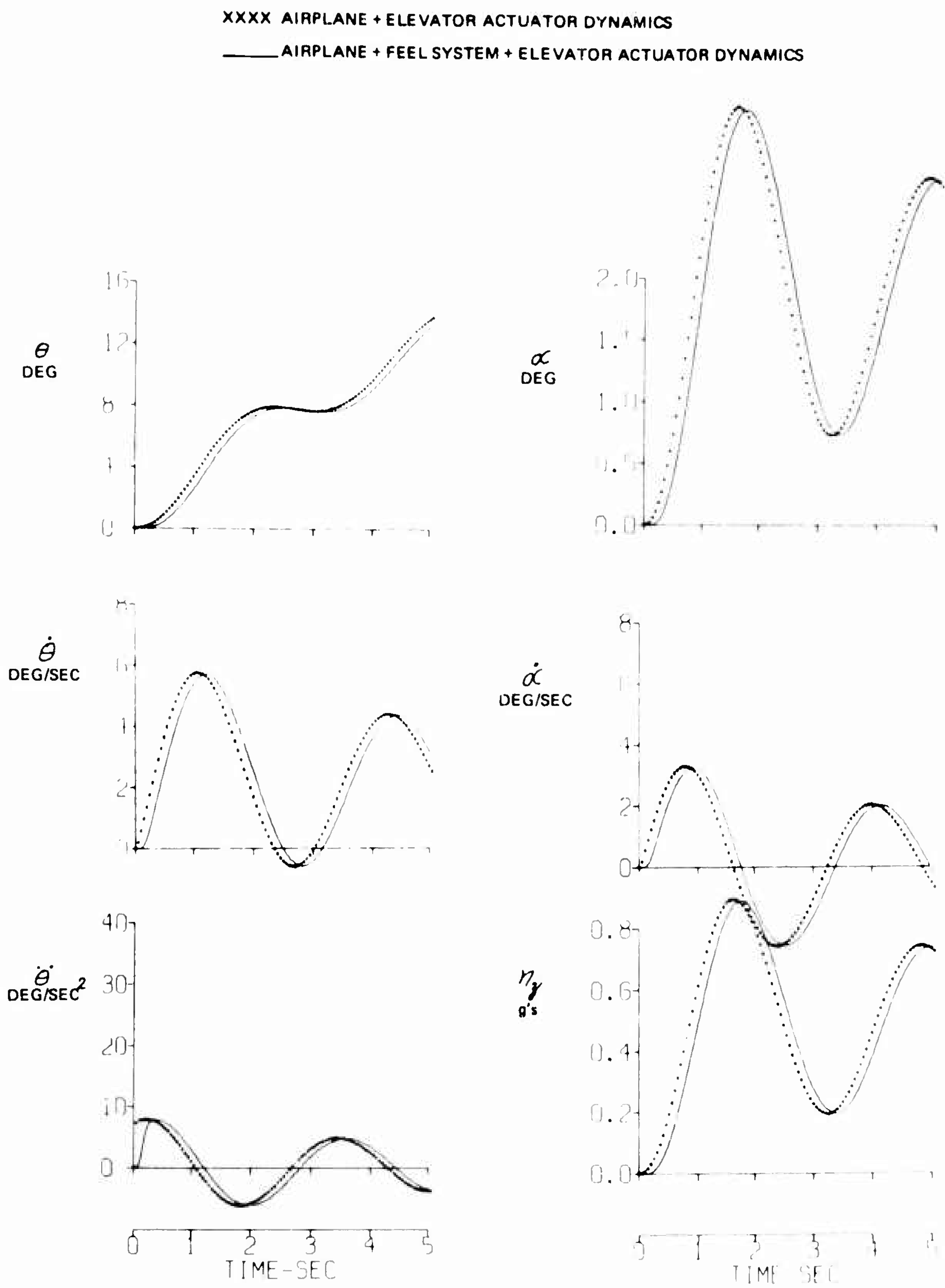


Figure IV-11 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP I, ω_{sp} = 1.96, ζ_{sp} =.077

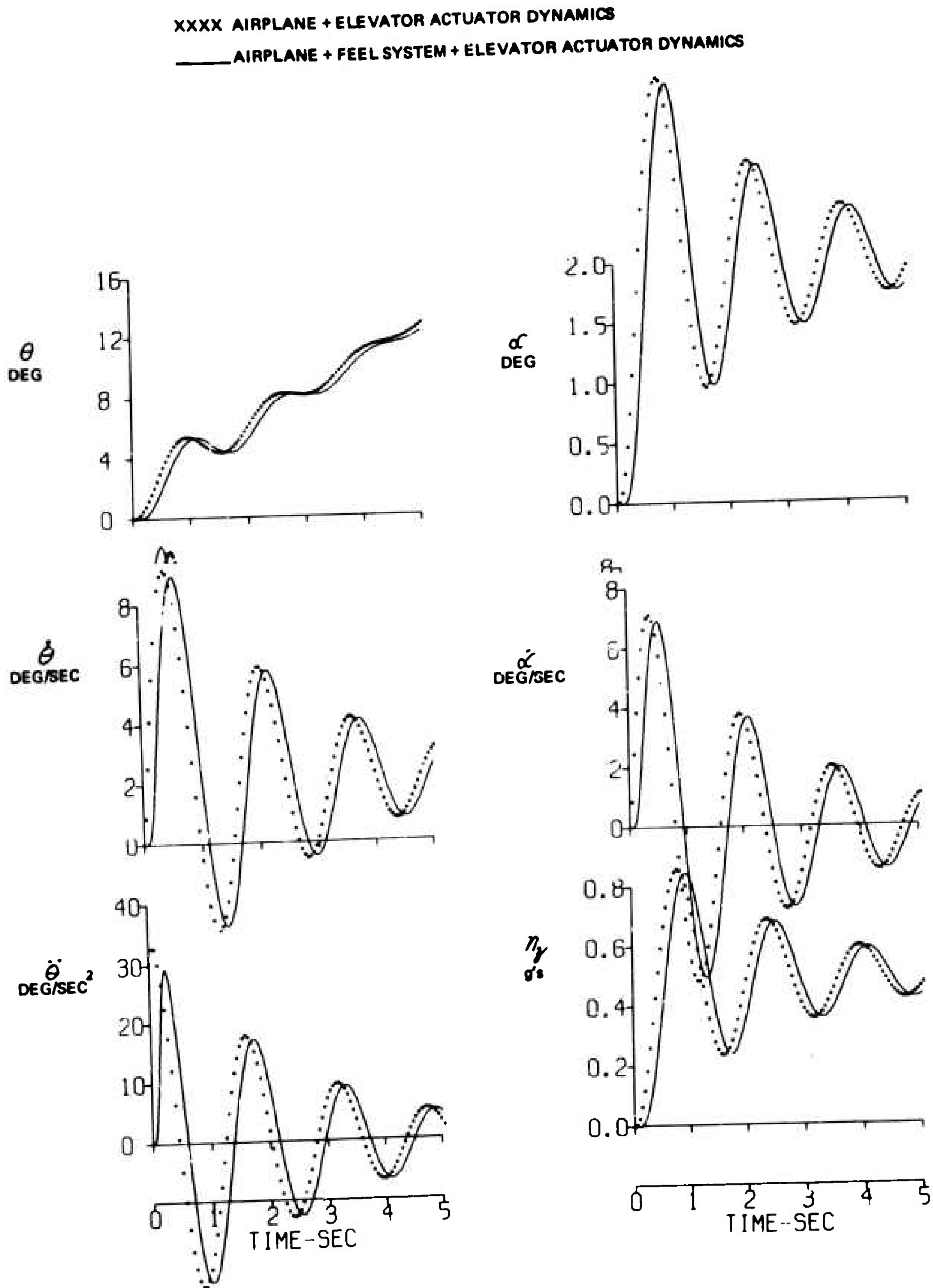


Figure IV-12 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP I, ω_{sp} = 4.02, ζ_{sp} = .10

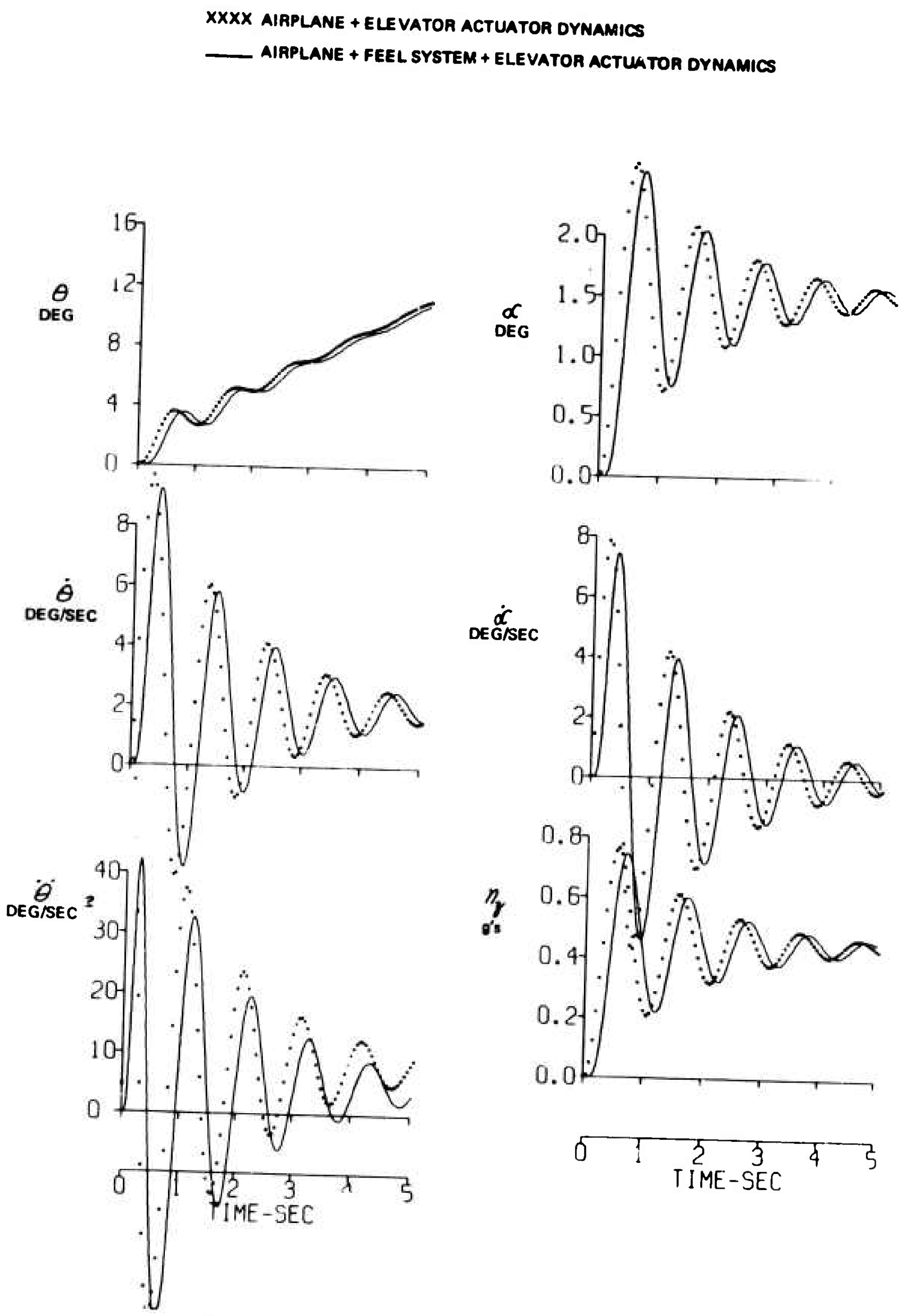


Figure IV-13 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP I, ω_{sp} = 6.09, ζ_{sp} = .10

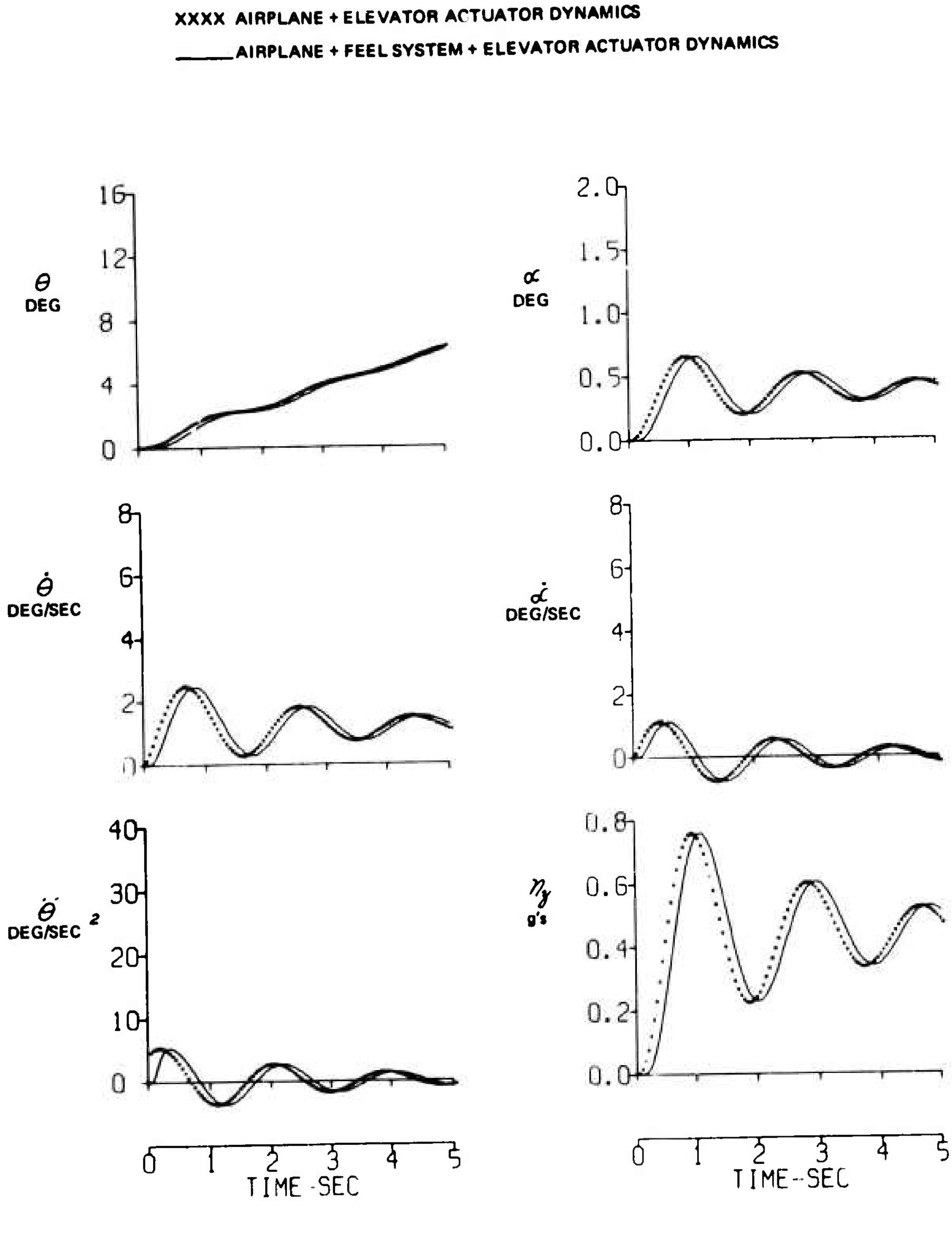


Figure IV-14 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP II, $\omega_{sp} = 3.40$, $\zeta_{sp} = .11$

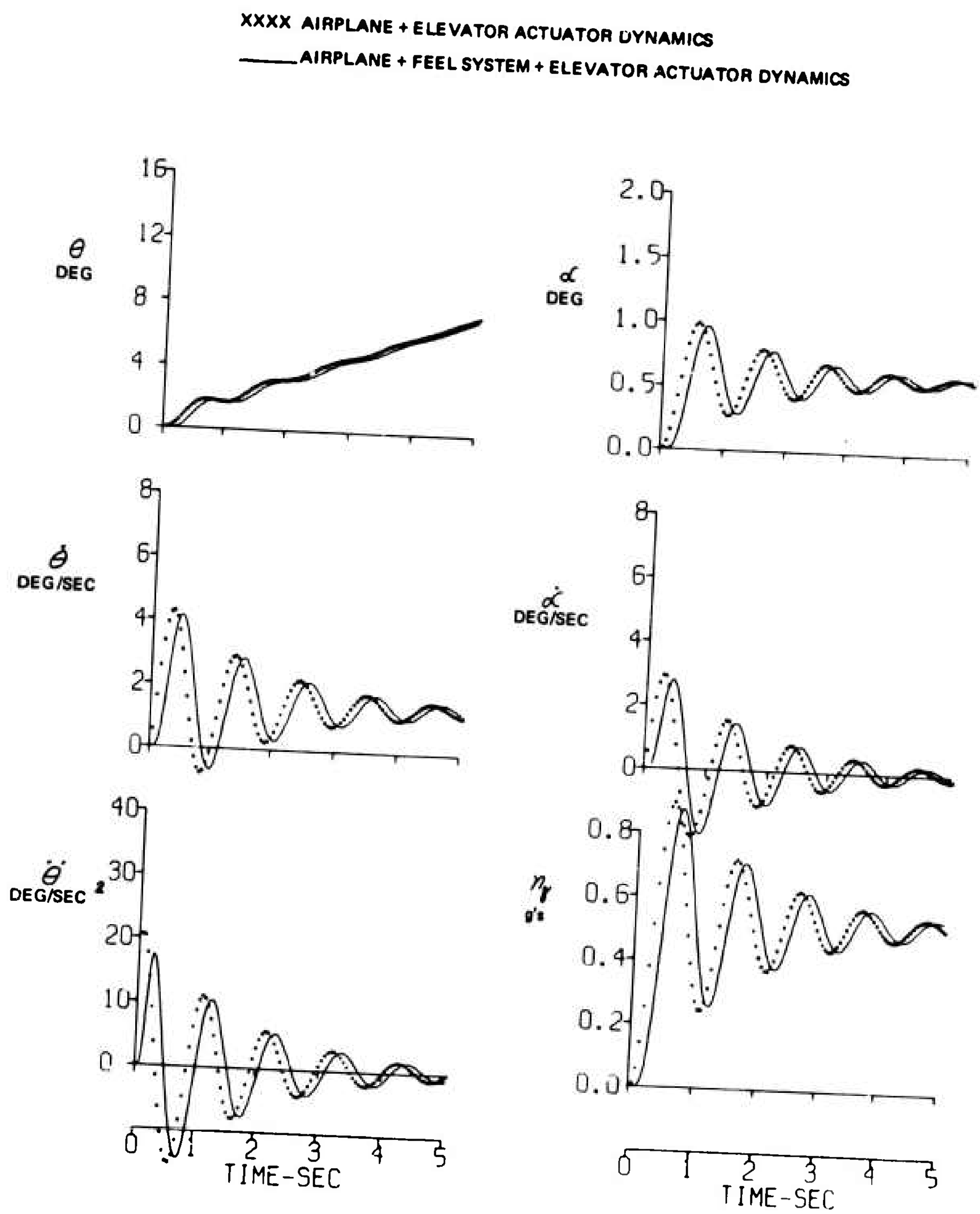


Figure IV-15 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP II ω_{sp} = 6.0, ζ_{sp} = .10

XXXX AIRPLANE + ELEVATOR ACTUATOR DYNAMICS

_____ AIRPLANE + FEEL SYSTEM + ELEVATOR ACTUATOR DYNAMICS

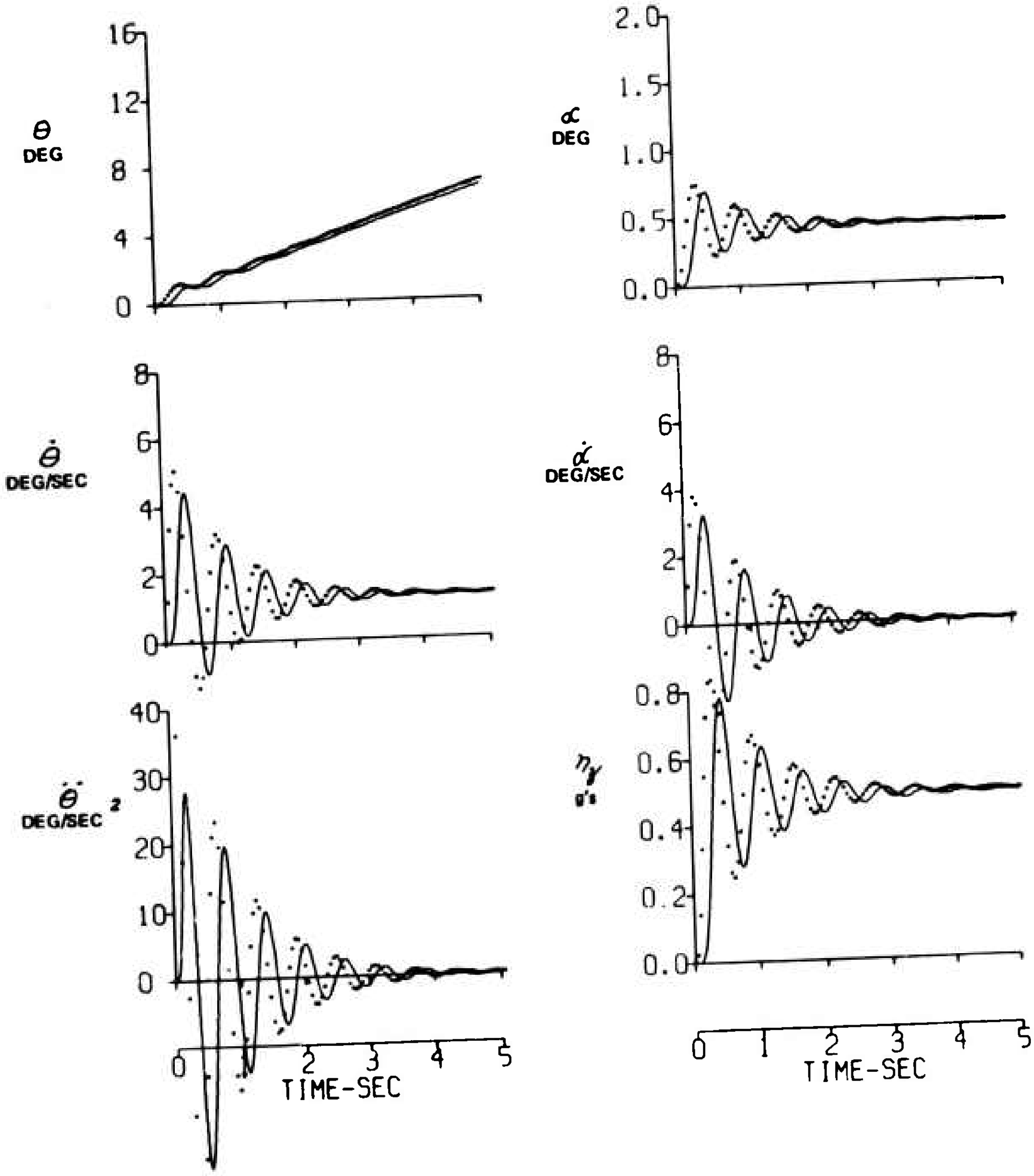


Figure IV-16 TIME HISTORY OF RESPONSE TO ELEVATOR STEP INPUT, GROUP II, ω_{sp} = 10.3, ζ_{sp} = .11

APPENDIX V

SIMULATION OF SHORT-PERIOD FREQUENCY AND DAMPING

With the assumption that velocity changes are negligible, the longitudinal short-period equations of motion for an airplane can be written as:

$$\dot{\alpha} = \dot{\theta} - L_{\alpha}\,\alpha - L_{\delta_e}\,\delta_e \qquad \text{(V-1)}$$

$$\ddot{\theta} = M_q\,\dot{\theta} + M_{\alpha}\,\alpha + M_{\dot{\alpha}}\,\dot{\alpha} + M_{\delta_e}\,\delta_e \qquad \text{(V-2)}$$

The solution of Equations V-1 and V-2 in terms of the dimensional stability derivatives yields the following expressions for the undamped natural frequency (ω_{sp}) and damping ratio (ζ_{sp}):

$$\omega_{sp}^{\,2} = -L_{\alpha} M_q - M_{\alpha} \qquad \text{(V-3)}$$

$$2\zeta_{sp}\,\omega_{sp} = L_{\alpha} - M_q - M_{\dot{\alpha}} \qquad \text{(V-4)}$$

$$\zeta_{sp} = \frac{L_{\alpha} - M_q - M_{\dot{\alpha}}}{2\sqrt{-L_{\alpha} M_q - M_{\alpha}}} \qquad \text{(V-5)}$$

Thus, by varying the values of the derivatives in Equations V-3 and V-4, the airplane's short-period frequency and damping ratio can be varied. In the variable stability T-33, it is only possible to vary L_{α} by varying the aircraft flight condition, which in turn varies the other derivatives. For this experiment, L_{α} was held fixed at two different values as discussed in Section III. If the T-33 elevator lift (L_{δ_e}) is neglected, it can be shown that the remaining derivatives can be varied independently by changing the gain settings in the response feedback loops to the elevator of the T-33 as shown below:

$$M_{\alpha} = (M_{\alpha})_{T\text{-}33} + \left(\frac{\delta_e}{\alpha}\right)(M_{\delta_e})_{T\text{-}33} \qquad \text{(V-6)}$$

$$M_{\dot{\alpha}} = (M_{\dot{\alpha}})_{T\text{-}33} + \left(\frac{\delta_e}{\dot{\alpha}}\right)(M_{\delta_e})_{T\text{-}33} \qquad \text{(V-7)}$$

$$M_q = (M_q)_{T-33} + \left(\frac{\delta_e}{q}\right)(M_{\delta_e})_{T-33} \qquad \text{(V-8)}$$

The quantities δ_e/α , $\delta_e/\dot{\alpha}$, and δ_e/q are the constant static gain settings to the elevator as a function of the airplane α , $\dot{\alpha}$, and q responses. The derivatives in Equations V-6, V-7, and V-8 are the T-33 derivatives for a given flight condition. The airplane short-period frequency and damping can then be varied by changing the gain settings to modify the T-33 derivatives.

Equations V-6, V-7, and V-8 indicate that each derivative is an independent function of only one gain. However, due to various sensor lags, coupled with the dynamics of the elevator actuator, the derivatives in actuality become a function dependent on all three gains.

Equation V-3 indicates that for a fixed L_α the short-period frequency can be varied by changing either M_q or M_α . The choice to vary one or the other of the derivatives or to vary both of them is somewhat arbitrary. The same holds true for the damping ratio which can be varied by changing M_q , $M_{\dot{\alpha}}$ or M_α for a fixed L_α . Since this program was originally designed to be a follow-on to the program described in Reference 10, it was decided that the derivatives would be modified in a manner similar to that used in Reference 10.

The preliminary gains for the calibration flights were determined analytically from the measured data obtained during the program described in Reference 10. The least-square-fit equations derived in that program related the short-period frequency and damping ratio to the aircraft fuel remaining and the feedback gains. These equations were modified to fit the wheel program and then used to calculate the static gains necessary to simulate the desired range of frequencies at a constant damping ratio (ζ_{sp} = .7). These gains were then flight tested in the initial calibration flights and subsequently modified as necessary to approximate the desired frequencies and damping ratio as closely as possible.

APPENDIX VI

SIMULATION OF WHEEL FORCE PER g AND CONTROL DEFLECTION PER g

The transfer function for $n_z(s)/F_{EW}(s)$ including the effects of the airplane's short-period dynamics, the feel system and notch filter as described in Section V, and the elevator actuator can be written as follows:

$$\frac{n_z(s)}{F_{EW}(s)} = \frac{\omega_{FS}^2 \omega_{ea}^2 \left(\frac{V_0}{g}\frac{1}{T_{\theta_2}} M_{\delta_e}\right)\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS}(s^2+4739)}{(s^2+2\zeta_{SP}\omega_{SP}s+\omega_{SP}^2)(s^2+2\zeta_{FS}\omega_{FS}s+\omega_{FS}^2)(s^2+2\zeta_{ea}\omega_{ea}s+\omega_{ea}^2)(s^2+275.3s+4739)} \quad \text{(VI-1)}$$

The steady state normal acceleration can be obtained from Equation VI-1 by using the final value theorem.

$$(n_z)_{SS} = \lim_{s\to\infty}\left[s\, n_z(s)\right] = \frac{\frac{V_0}{g}\frac{1}{T_{\theta_2}} M_{\delta_e}\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS}(F_{EW})_{SS}}{\omega_{SP}^2} \quad \text{(VI-2)}$$

Thus, the steady state wheel force per g can be expressed as:

$$\left(\frac{F_{EW}}{n_z}\right)_{SS} = \frac{\omega_{SP}^2}{\frac{V_0}{g}\frac{1}{T_{\theta_2}} M_{\delta_e}\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS}} \quad \text{(VI-3)}$$

One of the design requirements for this experiment was to maintain the control deflection per $g\,(\delta_{EW}/n_z)$ at 1 in./g. In order to accomplish this, the above expression was written in the following form:

$$\left(\frac{F_{EW}}{n_z}\right)_{SS}\left(\frac{\delta_{EW}}{F_{EW}}\right)_{SS} = \left(\frac{\delta_{EW}}{n_z}\right)_{SS} = \frac{\omega_{SP}^2}{\frac{V_0}{g}\frac{1}{T_{\theta_2}} M_{\delta_e}\left(\frac{\delta_e}{\delta_{EW}}\right)_{SS}} \quad \text{(VI-4)}$$

For a given flight condition, the control deflection per g is only a function of ω_{SP}^2 and $(\delta_e/\delta_{EW})_{SS}$. To obtain a $(\delta_{EW}/n_z)_{SS}$ of 1 in./g it was simply a matter of calibrating the $(\delta_e/\delta_{EW})_{SS}$ gain to correspond to the various simulated frequencies. A spring rate of 50 lb/in. was selected for use in this calibration. During the calibration flights, the $(\delta_e/\delta_{EW})_{SS}$ gain was then varied for each simulated frequency to obtain a wheel force per g of 50 lb/g. Once this was accomplished, the control deflection was essentially fixed at 1 in./g for all configurations at F_{EW}/n_z = 50 lb/g. To change the wheel force per g, the safety pilot had only to set the spring rate gain at a value equal in magnitude to the desired wheel force per g, this resulted in the proper variation of F_{EW}/n_z while maintaining a control deflection of 1 in./g.

APPENDIX VII
PILOT COMMENT DATA

TABLE IV-I PILOT COMMENT SUMMARY, PILOT A, FIXED $\frac{F_{EW}}{n_g}$

FLIGHT NO.	ω_{SP} RAD/SEC	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	F_{EW}/n_g LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATT... TR...
[illegible]	2.0?	.0?	6	1	GENERALLY THE AIRPLANE SEEMS A LITTLE SLUGGISH INITIALLY. I HAD NO REAL DIFFICULTY TRIMMING THE AIRCRAFT, HOWEVER I WAS NOT ABLE TO TRIM IT AS QUICKLY AS I WOULD LIKE. I DID HAVE SOME DIFFICULTY STOPPING ON A DESIRED ALTITUDE AFTER MAKING AN ALTITUDE CHANGE. THE AIRPLANE PERFORMANCE IN MAKING ALTITUDE CHANGES IS NOT AS GOOD AS I'D LIKE TO SEE. IN LARGE [illegible] ANGLE TURNS YOU GET THE NECESSARY g VERY EASILY. AS YOU EASE INTO THE STEADY STATE g THE STICK FORCES SEEM TO GET LIGHTER MOMENTARILY. AS YOU APPROACH THE STEADY STATE g THE FORCES LEVEL OUT AND ARE NOT UNDULY LIGHT.	THE STEADY STATE STICK FORCES ARE REASONABLE FOR A 3 g AIRCRAFT. I DIDN'T NOTICE ANY UNDESIRABLE STICK DISPLACEMENTS.	[illegible]	THE INITIAL RESPONSE TO THE PILOT'S INPUT IS A LITTLE SLOW, BUT ONCE YOU GET IT STARTED IT SEEMS A BIT FASTER. IT'S RESPONSE MAKES IT VERY HARD TO STOP THE AIRCRAFT ON A PRECISE ATTITUDE.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL IS NOT AS PRECISE AS I WOULD LIKE IT. THIS IS DUE TO THE SLUGGISH INITIAL RESPONSE AND THE SUBSEQUENT LIGHTENING OF THE STICK FORCES ONCE THE PITCH RATE GETS GOING	NO COMMENTS.
[illegible]	2.05	.00	2	1	IN GENERAL THE AIRPLANE IS QUITE GOOD. IT IS A SMOOTH TRACKING, GOOD FEELING AIRPLANE. I HAD NO PROBLEM TRIMMING AND THE AIRSPEED CONTROL WAS GOOD ONCE I GOT IT ALL SET UP. ALTITUDE CONTROL WAS GOOD. IT WAS VERY EASY TO ACQUIRE AND STABILIZE ON A NEW ALTITUDE. NO PROBLEM ENTERING TURNS OR HOLDING THE g IN TURNS. LONGITUDINAL CONTROL IN CLIMBING AND DESCENDING TURNS WAS GOOD.	THE STICK FORCES AND DISPLACEMENTS WERE REASONABLE. THERE IS NO TENDENCY TO INADVERTENTLY OVERSTRESS THE AIRPLANE. IT HAD A GOOD FEEL FOR ALLOWING YOU TO EASE UP TO THE LIMIT LOAD FACTOR, SO I DON'T THINK YOU WOULD OVERSTRESS THE AIRPLANE.	37.0	THE AIRCRAFT'S INITIAL RESPONSE TO A PILOT INPUT IS GOOD. IT'S NOT TOO ABRUPT, NOT TOO SLUGGISH, JUST NICE FEELING. THE FINAL RESPONSE IS FAIRLY GOOD. THE ONLY TIME I WOULD HAVE A COMPLAINT IS WHEN YOU TRY TO MAINTAIN VERY TIGHT CONTROL. THE AIRPLANE UNDER THESE CIRCUMSTANCES DOES HAVE A LITTLE TENDENCY TO BOBBLE. HOWEVER, YOUR INPUT MUST BE VERY SHARP IN ORDER TO SEE THIS.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL ARE GOOD. AGAIN THE ONLY PROBLEM WOULD BE THE SLIGHT TENDENCY TO BOBBLE WHEN YOU'RE MAINTAINING VERY TIGHT CONTROL.	I DON'T THINK THAT THE ATTITUDE TRACK... GRADED BY THE AIR... PERFORMANCE SEEMED... DEPENDENT ON HOW ... TO STAY WITH THE ...
[illegible]	3.05	.00	7	2	THE AIRPLANE IS NOT TOO BAD, BUT IT DOES HAVE SOME DEFICIENCIES WHICH I WOULD LIKE TO HAVE FIXED. MAKING ALTITUDE CHANGES PRESENTED NO PROBLEM, AS LONG AS THEY WERE MADE SLOWLY. LONGITUDINAL CONTROL IN TURNS IS SOMEWHAT DEGRADED BY THE FACT THAT IF YOU ROLL INTO A TURN QUICKLY AND TRY TO STABILIZE, YOU GET A LITTLE MORE g THAN YOU WANT. ONCE YOU'RE STABILIZED IN THE TURN EVERYTHING IS FINE. THERE WERE NO SPECIAL PROBLEMS CONNECTED WITH CLIMBING AND DESCENDING TURNS.	THE STICK FORCES AND THE DISPLACEMENTS DID NOT SEEM TOO BAD, BUT THE OVERALL RESPONSE IN FEEL WAS NOT QUITE ACCEPTABLE FOR A 3 g AIRPLANE. IT WOULD BE EASY TO OVERSTRESS THE AIRPLANE BECAUSE THE STICK FORCES SEEM LIGHT DURING THE TRANSIENT POSITION OF THE AIRPLANE'S RESPONSE. THE STICK FORCES IN THE STEADY STATE, HOWEVER, FELT OKAY.	00.0	THE INITIAL RESPONSE IS QUITE FAST, THEN YOU GET A LITTLE BOBBLE IN THE FINAL RESPONSE WHEN MAINTAINING TIGHT CONTROL.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL ARE DEGRADED BY THE FACT THAT WHEN YOU MAKE SUDDEN CHANGES IN ATTITUDE YOU TEND TO BOBBLE AROUND A LITTLE BEFORE GETTING SETTLED DOWN.	DURING THE TRACKI... SLIGHT TENDENCY TO... PUT FAST INPUTS IN... HAD A TENDENCY TO ... WHEN PERFORMING S... STAY WITH THE TRA... IT VERY EASY TO ... REALIZING IT. I ... WOULD BE A TENDENC... AIRPLANE IF IT ... A RAPID PULL UP.
001	4.0	.7	3	1.5	THE AIRPLANE IS REALLY NOT TOO BAD. I DON'T HAVE ANY MAJOR CRITICISM OF THE AIRPLANE. IN GENERAL, IT FEELS GOOD. I HAD NO PROBLEM WITH LONGITUDINAL CONTROL IN EITHER LEVEL OR CLIMBING AND DESCENDING TURNS. THE AIRPLANE IS EASY TO TRIM AND IT STAYS WHERE YOU PUT IT ONCE IT'S SET UP. ALTITUDE CONTROL IS NO PROBLEM. IT IS VERY EASY TO ACQUIRE AND STABILIZE ON A NEW ALTITUDE.	FEEL SYSTEM CHARACTERISTICS AND STICK FORCES FEEL GOOD ALL AROUND. THE STEADY STATE STICK FORCES ARE WHAT I CONSIDER GOOD FOR A 3 g AIRPLANE. I HAD NO TENDENCY TO OVERSTRESS THE AIRPLANE AND NO EXCESSIVE STICK DISPLACEMENTS.	00.0	THE AIRPLANE'S INITIAL RESPONSE TO A PILOT INPUT IS VERY NICE. I THINK IT FEELS VERY GOOD FOR THIS CLASS AIRPLANE. THE RESPONSE I GET IN RELATION TO THE STICK FORCE I APPLY IS VERY GOOD. I WOULD LIKE TO HAVE THIS TYPE OF RESPONSE IF I WERE GOING TO DO SOME LOW LEVEL WORK OR A TASK REQUIRING TIGHT TRACKING. THE FINAL RESPONSE HAS JUST A LITTLE BOBBLE. IF I PULL INTO A TARGET QUICKLY AND TRY TO STOP, THE AIRPLANE BOBBLES SLIGHTLY. THIS ONLY HAPPENS WHEN I MANEUVER SHARPLY. FOR SLOWER MANEUVERING, THE BOBBLE IS NOT PRESENT AND THE AIRPLANE HANDLES QUITE NICELY.	ATTITUDE AND NORMAL ACCELERATION CONTROL IS VERY GOOD. THE ONLY THING I NOTICE IS THAT IF I TRY TO PUT IN RAPID INPUTS AND STOP AT A PARTICULAR POINT, THE AIRPLANE BOBBLES A LITTLE.	I THINK MY PERFOR... TASKS IS STRICTLY ... LEVEL OF GAIN I ... PLANE. I DON'T T... DETRACTS FROM MY ...

A

ILOT A, FIXED $\frac{F_{EW}}{n_z}$ GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_z/\alpha \approx 16.5$ g/RAD, $\zeta_{SP} \approx 0.7$, V_T = 411 FT/SEC)

...TUDE ...AL CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
...AL ACCELERATION CON- ... AS I WOULD LIKE IT. ...GGISH INITIAL RESPONSE ...NTERING OF THE STICK ...RATE GETS GOING.	NO COMMENTS.	I DON'T THINK THE RANDOM DISTURBANCES AFFECTED MY OVERALL CONTROL TO ANY GREAT EXTENT.	THE AIRPLANE IS WELL DAMPED. THERE IS NO TENDENCY TO BOBBLE AROUND WHILE TRACKING A TARGET.	THE INITIAL RESPONSE IS SLUGGISH. THE STICK FORCES APPEAR TO BECOME LIGHTER BETWEEN THE INITIAL INPUT AND THE STEADY STATE.	THERE IS NO TENDENCY TOWARDS PIO. I WILL RATE THIS CONFIGURATION IN THE UNSATISFACTORY REGION BECAUSE I WOULD LIKE TO SEE SOME WORK DONE ON IT. I WOULD LIKE TO SEE SOMETHING DONE ABOUT THE SLUGGISH INITIAL RESPONSE AND THE APPARENT LIGHTENING OF FORCES DURING THE RESPONSE. BECAUSE OF THESE DEFICIENCIES, I WILL RATE THIS CONFIGURATION AN A-4.
...AL ACCELERATION CON- ...THE ONLY PROBLEM WOULD ... TO BOBBLE WHEN YOU'RE ... CONTROL.	I DON'T THINK THAT MY PERFORMANCE IN THE ATTITUDE TRACKING TASK WAS DE- GRADED BY THE AIRPLANE DYNAMICS. MY PERFORMANCE SEEMED TO BE ONLY DEPENDENT ON HOW PRECISELY I WANTED TO STAY WITH THE NEEDLE.	FOR CONTROL IN THE PRESENCE OF RANDOM DISTURBANCES, I DON'T THINK THAT THE AIRPLANE DYNAMICS MADE THE CONTROL ANY WORSE THAN YOU WOULD NORMALLY EXPECT TO SEE JUST DUE TO THE DISTURBANCES.	THE AIRPLANE FELT GOOD ALL AROUND. THE INITIAL RESPONSE, AND THE ABILITY TO TRACK PRECISELY AND ACCURATELY WERE GOOD.	THE ONLY OBJECTIONABLE FEATURE WOULD BE THE SLIGHT TENDENCY TO BOBBLE WHEN YOU'RE TRACKING VERY TIGHTLY.	I WOULD RATE THIS AIRPLANE AN A-2 INSTEAD OF AN A-1 BECAUSE OF THE VERY SLIGHT TENDENCY TO BOBBLE AROUND THE TARGET WHEN YOU'RE MAINTAINING TIGHT CONTROL.
...AL ACCELERATION ... THE FACT THAT ...ANGES IN ATTITUDE ...DO A LITTLE ...DOWN.	DURING THE TRACKING TASK, THERE WAS A SLIGHT TENDENCY TO BOB AROUND. IF YOU PUT FAST INPUTS INTO THE ELEVATOR YOU HAD A TENDENCY TO HUNT AROUND A LITTLE. WHEN PERFORMING STRAIGHT PULL-UPS TO STAY WITH THE TRACKING NEEDLE, I FOUND IT VERY EASY TO APPROACH 3G WITHOUT REALIZING IT. I CAN SEE WHERE THERE WOULD BE A TENDENCY TO OVERSTRESS THE AIRPLANE IF IT BECAME NECESSARY TO MAKE A RAPID PULL UP.	RANDOM DISTURBANCES CERTAINLY COMPOUND THE PROBLEM OF TRYING TO TRACK A TARGET PRECISELY. HOWEVER, NORMAL CONTROL IN THE PRESENCE OF RANDOM DISTURBANCES WAS NOT OVERLY DIFFICULT.	IT'S A FAIRLY NICE AIRPLANE WHEN IT'S MANEUVERED SLOWLY AND SMOOTHLY.	THE OBJECTIONABLE FEATURES INCLUDE, A TENDENCY TO BOBBLE WHEN YOU'RE MAIN- TAINING TIGHT CONTROL WHILE TRACKING A TARGET AND A TENDENCY TO OVER G THE AIRPLANE IN A RECOVERY OR PULL UP.	I WOULD GIVE IT A PIO RATING OF 2, BECAUSE WHEN YOU INITIATE AN ABRUPT MANEUVER OR ATTEMPT TIGHT CONTROL THERE IS A TENDENCY TO BOBBLE AROUND, HOWEVER IF YOU REDUCE YOUR GAIN THIS TENDENCY DISAPPEARS. THE AIRCRAFT HAS AN OBJECTIONABLE DEFICIENCY IN THAT THERE IS A TENDENCY TO OVER G THE AIRPLANE WHEN YOU'RE MAINTAINING TIGHT CONTROL. I DON'T THINK THIS MAKES THE AIRCRAFT UNACCEPTABLE BUT IT'S CERTAINLY UNSATISFACTORY. I THINK YOU COULD PERFORM THE MISSION AND I DON'T THINK THE LITTLE BOBBLE TENDENCY WHILE TRACKING WOULD BE ENOUGH OF A DEFICIENCY TO RATE THE A/C UNACCEPTABLE. I DO THINK THAT A PILOT UNDER COMBAT STRESS WOULD DEFINITELY HAVE A TENDENCY TO OVER G THE AIRPLANE ON PULL OUTS. BECAUSE OF THIS, I'M RATING THE AIRPLANE U-7.
...CELERATION ...THE ONLY THING ...TRY TO PUT IN ...AT A PARTICULAR ...BLES A LITTLE.	I THINK MY PERFORMANCE IN THE TRACKING TASKS IS STRICTLY DEPENDENT ON THE LEVEL OF GAIN I USE TO FLY THE AIR- PLANE. I DON'T THINK THE AIRPLANE DETRACTS FROM MY PERFORMANCE AT ALL.	RANDOM DISTURBANCE INPUTS DO NOT CHANGE THE AIRPLANE CONTROL CHARACTERISTICS A WHOLE LOT. I CAN SEE MY PERFORMANCE GO DOWN BECAUSE OF THE RANDOM DISTURBANCES, BUT I DON'T THINK THE AIRPLANE DYNAMICS CONTRIBUTE MUCH TO THIS DEGRADATION OF PERFORMANCE.	THIS IS A NICE FEELING, RESPONSIVE AIRPLANE. STICK FORCES ARE REASON- ABLE WHEN I START A MANEUVER AND EVERYTHING FEELS NICE WHEN I AM TRACKING OR VISUALIZING SOME LOW LEVEL TERRAIN-FOLLOWING OR FLYING FORMATION. THE AIRPLANE JUST FEELS NICE AND TIGHT; IT'S NOT OVERLY SENSITIVE, YET RESPONSIVE ENOUGH THAT I HAVE FAIRLY GOOD CONTROL.	THE ONLY OBJECTIONABLE FEATURE IS THE SLIGHT BOBBLE I GET WHEN I ATTEMPT TIGHT, ABRUPT CONTROL OF THE AIRPLANE.	THERE IS A LITTLE BOBBLE IF YOU ATTEMPT TIGHT CONTROL. I THINK IT'S A PIOR OF 1.5. I THINK THE AIRPLANE IS SATISFACTORY. THERE IS THIS LITTLE BOBBLY TENDENCY, BUT NOTHING I WOULD COMPLAIN VERY HEAVILY ABOUT.

B

TABLE IV-I (Continued) PILOT COMMENT SUMMARY, PILOT A, FIXED $\frac{F_{EW}}{n_z}$

FLIGHT NO.	ω_{sp} $\frac{RAD}{SEC}$	ζ_{sp}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_z}$ LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
086	5.46	.50	1.5	1	THIS IS A VERY GOOD AIRPLANE. TRIMABILITY AND AIRSPEED CONTROL ARE BOTH GOOD. MY ABILITY TO ACQUIRE AND STABILIZE ON A NEW ALTITUDE WAS GOOD. LONGITUDINAL CONTROL IN LEVEL AND CLIMBING OR DESCENDING TURNS WAS GOOD.	STICK FORCES FEEL VERY GOOD, AND I HAVE NO OBJECTIONS TO THE STICK DISPLACEMENTS.	52.0	AIRPLANE RESPONSE TO PILOT INPUTS FEELS GOOD ALL AROUND. INITIAL RESPONSE IS NICE AND NOT ABRUPT NOR SLUGGISH. YOU GET JUST WHAT YOU EXPECT TO FEEL WHEN YOU PULL INTO A MANUEVER. THE SAME IS TRUE WHEN YOU REACH A STEADY STATE. THE FINAL RESPONSE IS VERY NICE.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL ARE GOOD IN THE TYPICAL TRACKING MANUEVER. THERE IS A VERY SLIGHT TENDENCY FOR THE NOSE TO FISH AROUND A LITTLE IF YOU PUT IN EXTREMELY ABRUPT INPUTS. FOR NORMAL INPUTS HOWEVER THIS IS A VERY NICE FLYING MACHINE.	MY ATTITUDE TRACKING TASK PE[illegible] IS SOME OF THE BE[illegible] I'VE HAD [illegible] ABLE TO TRACK AS PRECISELY A[illegible]
079	6.10	.75	3	1	I DIDN'T HAVE ANY REAL DIFFICULTY WITH THIS CONFIGURATION. NO PROBLEM HOLDING THE AIRPLANE AT A PARTICULAR ATTITUDE WHILE YOU TRIM. ALTITUDE CONTROL IS GOOD AS LONG AS YOU MAKE CHANGES RELATIVELY SLOWLY. I HAD NO PROBLEMS AT ALL WITH LONGITUDINAL CONTROL IN TURNS.	STICK FORCES SEEM REASONABLE FOR A 3.6 AIRPLANE. I DON'T THINK YOU WOULD INADVERTENTLY OVERSTRESS THE AIRPLANE. I DIDN'T HAVE ANY CONSCIOUS AWARENESS OF OF STICK DISPLACEMENTS. SO I'D SAY THEY ARE REASONABLE.	50.3	THE INITIAL RESPONSE IS GOOD. IT SEEMS TO COME ON JUST THE WAY YOU WANT IT, NOT TOO FAST OR TOO SLOW. THE FINAL RESPONSE IS WHERE YOU SEE A LITTLE PROBLEM. IF YOU EASE INTO YOUR TRACKING MANUEVER EVERYTHING IS FINE. HOWEVER IF YOU ARE MORE AGGRESSIVE WITH YOUR INPUTS THE AIRPLANE TENDS TO BOBBLE OR OVERSHOOT A LITTLE IN THE FINAL RESPONSE.	HOLDING AN ATTITUDE OR MAINTAINING A STEADY-STATE g IS NO PROBLEM. ONLY WHEN YOU'RE DOING VERY TIGHT TRACKING DO YOU NOTICE THIS SLIGHT BOBBLING TENDENCY.	MY PERFORMANCE IN THE TRACKI[illegible] MORE OR LESS A FUNCTION OF [illegible] OTHER WORDS MY PERFORMANCE [illegible] DETERMINATED BY THE DYNAMICS [illegible] AIRCRAFT.
084	7.55	.66	4	3	THIS AIRCRAFT IS NOT AS GOOD AS I WOULD LIKE TO SEE. MY ABILITY TO TRIM WAS FAIRLY GOOD. THE PROBLEMS ARISE WHEN YOU TRY TO MAKE SMALL PERTURBATION MANUEVERS AROUND LEVEL FLIGHT. IF YOU MANUEVER QUICKLY THE AIRPLANE INITIALLY SEEMS VERY RESPONSIVE THEN IT HESITATES STARTS QUICKLY AGAIN AND TENDS TO BOBBLE AROUND A BIT. THE CONTROL IN TURNS IS GENERALLY FAIRLY GOOD. HOWEVER, IF YOU ROLL INTO THE TURN RAPIDLY AND TRY TO STABILIZE QUICKLY, YOU GET THIS STOP AND GO ACTION. IF YOU EASE INTO THE TURNS, THERE IS NO PROBLEM.	INITIALLY THE STICK FORCES SEEM TO BE OKAY. AS YOU APPROACH 2 g OR SO THE FORCES SEEM TO BE A LITTLE TOO HEAVY. I CERTAINLY DON'T THINK YOU WOULD INADVERTENTLY PULL OVER 3 g. STICK DISPLACEMENTS WERE GOOD.	61.5	THE AIRPLANE IS INITIALLY VERY RESPONSIVE. THEN IT SEEMS TO HESITATE AND START UP AGAIN. IT FEELS LIKE A STOP AND GO TYPE MOTION. THE FINAL RESPONSE SEEMS TO BE A LITTLE BOBBLY.	AS LONG AS YOU MAINTAIN A STEADY ATTITUDE THE AIRPLANE FLIES WELL. HOWEVER WHEN YOU TRY TO MAKE THE SMALLEST CORRECTION THE AIRPLANE STARTS TO OSCILLATE. YOU HAVE TO DECREASE YOUR GAIN SLIGHTLY AND EASE ONTO THE TARGET RATHER THAN PLACING THE AIRCRAFT RIGHT WHERE YOU WANT IT IN AN ABRUPT MANNER. WHEN YOU TRY TO DO SOMETHING ABRUPTLY IN A LARGE [illegible] MANUEVER, YOU GET THE FEELING THAT IT STARTS MOVING THEN SORT OF HESITATES A LITTLE AND THEN LEAPS OUT AGAIN.	THE STOP AND GO ACTION TENDS TO [illegible] DUCE YOUR ACCURACY IN THE TRAC[illegible] TASKS WHEN YOU TRY TO DO THI[illegible] QUICKLY.
087	7.66	.64	4	2	THIS IS A FAIR AIRPLANE WITH A SLIGHT TENDENCY TO BOBBLE SOMEWHAT IN A TIGHTER TRACKING AREA BUT IT IS NOT A REAL DIFFICULT PROBLEM. SOME DIFFICULTY IN TRIMMING THE AIRPLANE WITH A SLIGHT TENDENCY TO BOBBLE THE AIRPLANE ABOUT THE TRIM POSITION.	THE STEADY STATE STICK FORCES WERE MEDIUM TO HEAVY. YOU DO HAVE GOOD 3 g PROTECTION AND NO PROBLEM AS FAR AS STICK DISPLACEMENTS. YOU ARE NOT APT TO PULL THE AIRPLANE APART.	61.0	THE INITIAL RESPONSE WHEN YOU ARE MAKING A SMALL CORRECTION IS QUITE FAST ALTHOUGH NOT OVERLY SENSITIVE. THE INITIAL RESPONSE IS CERTAINLY QUICK AND A LITTLE BIT SENSITIVE. THE FINAL RESPONSE IS LESS THAN SATISFACTORY. DEPENDING ON HOW TIGHT YOU WISH TO CONTROL YOUR ATTITUDE YOU GET A LITTLE BOBBLE WHEN YOU TRY TO STOP THE FINAL MOTION. FOR SLOWER INPUTS YOU HAVE A FAIRLY PRECISE AIRPLANE AND THE AMOUNT OF BOBBLE DEPENDS STRICTLY ON HOW TIGHT YOU TEND TO FLY THE AIRPLANE.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL IS REALLY NO PROBLEM. EVEN THOUGH YOU MAY SEE THE SMALL BOBBLE IT TENDS TO DISAPPEAR IN THE COURSE OF MANEUVERING. STEADY STATE g AND STEADY STATE PITCH RATES ARE SATISFACTORY. YOU DO TEND TO BOBBLE THE AIRPLANE WHEN TIGHTENING UP ON YOUR ATTITUDE CONTROL. WHEN FLYING THE AIRPLANE SLOWLY YOU DO NOT SEE THE BOBBLE.	IN THE ATTITUDE TRACKING TASK, [illegible] WANT VERY, VERY TIGHT CONTROL [illegible] BOBBLE TENDS TO REDUCE YOUR PE[illegible] AT THE PILOT GAIN I WISH TO [illegible] BAR [illegible] DIDN'T REALLY FEEL THAT [illegible] BOBBLE WAS DETRIMENTAL; MY OVERAL[illegible] FORMANCE.

A

LOT A, FIXED $\frac{F_{EW}}{n_z}$ GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_z/\alpha \approx 16.5$ g/RAD, $\zeta_{SP} \approx 0.7$, $V_T = 411$ FT/SEC)

	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
A- CAL Y TISH AL ICE	MY ATTITUDE TRACKING TASK PERFORMANCE IS SOME OF THE BEST I'VE HAD. I WAS ABLE TO TRACK AS PRECISELY AS I WISHED.	THE RANDOM DISTURBANCE INPUTS DID NOT AFFECT MY CONTROL TO ANY GREAT EXTENT.	THE AIRPLANE FEELS VERY GOOD. THE FORCES WERE REASONABLE AND THE RESPONSE WAS THE TYPE THAT I LIKE TO SEE WHEN I'M MANEUVERING.	NONE.	NO TENDENCY TO INDUCE UNDESIRABLE MOTIONS. PIOR-1. ONLY WHEN YOU FLY THE AIRCRAFT WITH EXTREMELY ABRUPT INPUTS DO YOU SEE ANYTHING UNDESIRABLE. THERE IS A VERY SLIGHT TENDENCY TO BOBBLE AROUND THE TARGET. I WOULD RATE IT AN A-1.5 OVERALL.
S A Y WHEN DO	MY PERFORMANCE IN THE TRACKING TASKS WAS MORE OR LESS A FUNCTION OF MY GAIN. IN OTHER WORDS, MY PERFORMANCE WAS NOT DETERIORATED BY THE DYNAMICS OF THE AIRCRAFT.	I DON'T THINK MY PERFORMANCE WAS DETERIORATED BY THE RANDOM DISTURBANCE ANY MORE THAN YOU WOULD EXPECT. I DON'T THINK THERE WAS ANY DETRIMENTAL INTERACTION BETWEEN THE DISTURBANCES AND THE DYNAMICS OF THE AIRPLANE.	THE AIRPLANE WAS FAIRLY GOOD RESPONDING.	IN TIGHT TRACKING MANEUVERS THERE WAS A SLIGHT TENDENCY TO OVERSHOOT OR BOBBLE.	NO TENDENCY TO INDUCE PIO. I'LL RATE IT A 1. THE AIRPLANE IS ACCEPTABLE AND SATISFACTORY. I COULD DO THE MISSION. I WOULD HAVE THESE BOBBLES FIXED IF POSSIBLE. I'LL RATE IT AN A-3.
T' - VER CON- ILIATE GHT'.' DAN OU WANT RY TO YES A	THE STOP AND GO ACTION TENDS TO REDUCE YOUR ACCURACY IN THE TRACKING TASKS WHEN YOU TRY TO DO THINGS QUICKLY.	IF YOU TRY TO KEEP THE AIRCRAFT ON A TARGET IN THE PRESENCE OF RANDOM DISTURBANCES, ANY SMALL CORRECTION YOU MAKE GIVES YOU THIS SLIGHT BOBBLE. CONTROL JUST WASN'T VERY GOOD.	THE AIRPLANE IS O.K. IF FLOWN SMOOTHLY AND MANEUVERED SLOWLY.	THE STOP AND GO TYPE ACTION THE AIRCRAFT EXHIBITS IN RESPONSE TO ABRUPT INPUTS. THE BOBBLING TENDENCY WHEN MAKING SMALL CORRECTIONS ABOUT LEVEL FLIGHT.	UNDESIRABLE MOTIONS ARE EASILY INDUCED WHEN THE PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. THESE MOTIONS CAN BE PREVENTED OR ELIMINATED BUT ONLY BY SACRIFICING TASK PERFORMANCE. I THINK A PIOR OF 3 IS GOOD FOR THIS AIRPLANE. I CERTAINLY DO FEEL THAT I WOULD LIKE TO SEE THE DEFICIENCIES I DESCRIBED FIXED. HOWEVER, I DO FEEL THAT I COULD PERFORM THE MISSION. I THINK IT IS NO WORSE THAN AN A 4 BECAUSE YOU DON'T REALLY NEED CONSIDERABLE PILOT COMPENSATION. YOU CAN EASILY COMPENSATE FOR IT BUT YOUR PERFORMANCE TENDS TO DETERIORATE. I WOULD RATE IT AN A-4 BECAUSE OF THIS TENDENCY TO BOBBLE AROUND ON THE TARGET WHEN YOU MAKE SMALL TIGHT CORRECTIONS.
- EVEN LE E OF READY Y. E E DE SLOWLY	IN THE ATTITUDE TRACKING TASK, IF YOU WANT VERY, VERY TIGHT CONTROL, A SMALL BOBBLE TENDS TO REDUCE YOUR PERFORMANCE. AT THE PILOT GAIN I WISHED TO TRACK THE BAR, I DIDN'T REALLY FEEL THAT THE BOBBLE WAS DECREASING MY OVERALL PERFORMANCE.	THE AIRPLANE BOBBLES AROUND SOMEWHAT IN THE PRESENCE OF THE RANDOM DISTURBANCES BUT I DON'T THINK MY PERFORMANCE IS DEGRADED A WHOLE LOT.	THE AIRPLANE, IN GENERAL, IS FAIRLY PRECISE IN WHAT YOU CAN DO WITH IT.	THE SMALL BOBBLE YOU SEE IN THE FINAL PART OF THE AIRPLANE RESPONSE IS OBJECTIONABLE. HOWEVER, THIS IS A FUNCTION OF HOW TIGHT YOU ATTEMPT TO CONTROL IT.	UNDESIRABLE MOTIONS TEND TO OCCUR WHEN THE PILOT INITIATES A ROUGH MANEUVER BUT THEY CAN BE PREVENTED BY REDUCING PILOT GAIN. I FEEL I CAN DO THE MISSION BUT I WOULD LIKE TO SEE THIS TENDENCY TO BOBBLE FIXED. THE MAIN DEFICIENCY IS THIS TENDENCY TO BOBBLE THE AIRPLANE WHEN YOU ARE TRYING TO TRACK TIGHTLY. HOWEVER, THIS IS NOT TOO MUCH OF A PROBLEM IF THE PILOT TENDS TO SLACK OFF ON HIS CONTROL GAIN.

B

TABLE IV-II PILOT COMMENT SUMMARY, PILOT B, FIXED $\frac{F_{EW}}{n_g}$ G…

FLIGHT NO.	ω_{SP} $\frac{RAD}{SEC}$	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_g}$ LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	
007	1.97	.69	4	3	THIS IS A FAIR CONFIGURATION. MY PRIMARY OBJECTION IS THAT IT'S A LITTLE SLUGGISH. TRIMABILITY WAS ADEQUATE. ALTITUDE CONTROL WAS NO PROBLEM. LONGITUDINAL CONTROL IN TURNS, ENTRY AND RECOVERY, DIDN'T SEEM TOO BAD. I THOUGHT I COULD DO A FAIR JOB OF MAKING LEVEL TURNS. PRECISION CONTROL OF RATE OF CLIMB OR DESCENT WAS A LITTLE DIFFICULT IN TURNS. IT'S JUST NOT PRECISE ENOUGH FOR VERY SMALL CORRECTIONS.	STICK FORCES WERE MODERATE. THEY CERTAINLY WEREN'T HEAVY. I MIGHT HAVE LIKED JUST SLIGHTLY LESS FORCE. I GOT THE IMPRESSION I WAS USING A PRETTY FAIR AMOUNT OF STICK DISPLACEMENT. I THINK THIS WAS PRIMARILY BECAUSE I WAS TRYING TO SPEED UP THE AIRPLANE RESPONSE.	47.9	I THOUGHT THE INITIAL RESPONSE WAS A LITTLE SLUGGISH. I HAD A DEFINITE TENDENCY TO TRY TO OVERDRIVE THE AIRPLANE INITIALLY. FINAL RESPONSE WASN'T TOO BAD.	THE SLUGGISHNESS WAS MOST NOTICEABLE IN THE PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL. I HAD A STRONG TENDENCY TO OVERSHOOT BOTH IN ATTITUDE AND ACCELERATION. WHEN I ADJUSTED MY GAIN, I COULD REDUCE MY OVERSHOOT TO ALMOST ZERO. THE TRACKING CAPABILITY WAS FAIR TO POOR. YOU COULD TRACK WITHOUT OVERSHOOTING BUT ONLY BY ADJUSTING YOUR GAIN SO AS TO NOT FORCE THE AIRPLANE	IN THE STEP … NESS OF THE … TO OVERSHOOT … RANDOM INPUT … DENCY TO OVE… JUST ISN'T … FOR THE SMALL…
008	2.0	.70	5	3	I THINK THE AIRPLANE IS GENERALLY TOO SLUGGISH FOR A GOOD TRACKING AIRCRAFT, AS MIGHT BE REQUIRED IN THE REFUELING MISSION. THE AIRPLANE FEELS SORT OF SOFT. THE SHORT PERIOD FREQUENCY MUST BE QUITE LOW BUT THE DAMPING IS GOOD. I HAD SOME DIFFICULTY ESTABLISHING A STEADY STATE g IN TURNS. I ALSO HAD SOME DIFFICULTY IN ESTABLISHING A DESIRED RATE OF CLIMB OR DESCENT IN TURNS. WHAT I HAD TO DO WAS TO MAKE A RATHER LARGE INPUT, THEN TAKE SOME OF IT OUT TO KEEP FROM OVERSHOOTING THE DESIRED g. THE PILOT ATTEMPTS TO DRIVE THE AIRPLANE TO RESPOND QUICKER THAN THE AIRPLANE DYNAMICS WILL ALLOW. THE LATERAL-DIRECTIONAL CONTROL DID SEEM TO HAVE SOME EFFECT ON MY MANEUVERING CAPABILITY. I HAD THE FEELING THAT THE LATERAL RESPONSE WAS JUST TOO SLUGGISH. A SPECIAL PILOTING TECHNIQUE IS REQUIRED IN THAT THE PILOT PUTS IN A SHARP INPUT TO GET THE RESPONSE GOING, AND THEN TAKES OUT THE INPUT TO KEEP FROM OVERSHOOTING. IN OTHER WORDS, HE HAS TO FLY BY USING PULSE TYPE INPUTS.	I THOUGHT THE STICK FORCES WERE MODERATE AND THE STICK DISPLACEMENTS MODERATE TO LARGE. IT SEEMED AS THOUGH THE DISPLACEMENTS CONTRIBUTED TO THE SOFTNESS OF THE FEEL AND TIED IN WITH THE SLUGGISH RESPONSE.	47.9	THE INITIAL RESPONSE OF THE AIRCRAFT IS TOO SLOW. I WOULD MUCH PREFER A MORE RESPONSIVE AIRCRAFT. TRYING TO OBTAIN A STEADY STATE g IS SOMEWHAT OF A PROBLEM. I INVARIABLY OVERSHOOT THE DESIRED g. EVEN WHEN I REDUCED MY INPUT GAIN, I STILL OVERSHOT SOMEWHAT.	THERE IS A DEFINITE TENDENCY TO OVERSHOOT DESIRED PITCH ATTITUDES AND g LEVELS. PITCH ATTITUDE CONTROL CAN BE IMPROVED BY MAKING SLOWER INPUTS, BUT THEN YOU HAVE A VERY SLUGGISH AIRPLANE.	THE CHARACTER… AS SLUGGISHNE… DRIVE THE PIT… CELERATION … TRACKING TASK… I NEVER REALLY… TIGHT ATTITUD…
009	4.05	.65	1.5	1	I THOUGHT THAT OVERALL THIS IS PROBABLY A VERY GOOD CONFIGURATION FOR THE MISSION. THE ONLY RESERVATION I HAD WAS THAT MAYBE THE STICK FORCES WERE A LITTLE ON THE HIGH SIDE. I'M NOT REALLY SURE OF THIS, HOWEVER, SINCE I GOT INTO BUFFET AT ABOUT 1.5 INCREMENTAL g. BUT EVEN THEN I FELT THAT MAYBE THE FORCES WERE A LITTLE HIGH. THE INITIAL FORCES SEEMED TO BE COMFORTABLE, MAYBE EVEN A LITTLE LIGHT. THE TRIMABILITY WAS EXCELLENT. ALTITUDE CONTROL WAS QUITE EASY, VERY GOOD. LONGITUDINAL CONTROL IN TURNS ENTRIES, MAINTAINING THE TURN, AND RECOVERY I THOUGHT WAS EXCELLENT. I THOUGHT CLIMBING AND DESCENDING TURNS WERE VERY EASY TO MAKE.	THE INITIAL STICK FORCE WAS GOOD. IF ANYTHING IT MAY HAVE BEEN SLIGHTLY LIGHT. STICK DISPLACEMENTS APPEARED TO BE COMFORTABLE. IN SYMMETRICAL PULL-UPS THE STICK FORCE GRADIENT FELT BETTER THAN IT DID IN A STEADY TURN. THE FORCE IN THE TURN WAS JUST ENOUGH HIGHER THAN THAT IN THE SYMMETRICAL PULL-UP TO MAKE ME THINK IT WAS A LITTLE TOO HEAVY.	37.0	THE INITIAL RESPONSE WAS QUITE GOOD FOR THIS CLASS AIRPLANE. THERE WAS NO PROBLEM IN MAINTAINING A STEADY STATE EXCEPT THAT I FELT THE FORCES WERE A LITTLE HIGH.	PITCH ATTITUDE CONTROL WAS GOOD. NORMAL ACCELERATION CONTROL I THOUGHT WAS EXCELLENT.	THE STEP INPU… EASY AND I TH… GOOD. THERE W… OVERCONTROL F… ON THE RANDOM … THAT I HAD TO … FROM OVERSHOOT… ACCURATELY BUT… INPUTS THERE W…
004	4.15	.65	2	2	IN GENERAL A PRETTY GOOD AIRPLANE; I CAN'T SEE ANYTHING GROSSLY INADEQUATE ABOUT THIS AIRPLANE. I THINK I WOULD POSSIBLY LIKE TO HAVE THE AIRPLANE A LITTLE MORE RESPONSIVE IN PITCH. I LIKE THE STICK FORCE GRADIENT, ALTHOUGH IT IS SLIGHTLY LIGHT AND THERE IS A SLIGHT TENDENCY TO OVERSHOOT IN THE TRACKING TASKS. THE OVERALL IMPRESSION IS THAT IT'S A GOOD AIRPLANE.	I LIKED THE STEADY STATE STICK FORCE AND IN GENERAL FELT THE FORCES WERE GOOD BUT POSSIBLY FOR THIS CLASS OF AIRCRAFT THEY MIGHT BE JUST A LITTLE ON THE LIGHT SIDE, PROBABLY NOT MUCH BUT SLIGHTLY. BECAUSE OF THE MODERATE SHORT PERIOD FREQUENCY I BELIEVE I HAVE A TENDENCY TO POSSIBLY OVERDRIVE THE AIRPLANE A LITTLE AND THIS GIVES THE IMPRESSION OF LARGER STICK MOTIONS NOT A MAJOR POINT BUT NOTICEABLE. I I WOULD SAY THE STICK DISPLACEMENTS ARE MODERATE.	41.1	I BELIEVE THE INITIAL RESPONSE WAS JUST A LITTLE BIT SLUGGISH AND I HAD A SLIGHT TENDENCY TO OVERSHOOT IN THE FINAL RESPONSE. POSSIBLY I WAS OVERDRIVING THE AIRPLANE A LITTLE BIT BUT THE STEADY-STATE WAS OKAY AND THE ABILITY TO CONTROL THE AIRPLANE FOR SMALL AMPLITUDE ACCELERATIONS IN A TURN WAS RATHER GOOD.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WASN'T QUITE AS GOOD AS I EXPECTED. IF I KEPT MY GAIN DOWN I WAS A LITTLE BIT SLOW IN REDUCING THE TRACKING ERROR TO ZERO AND IF I PICKED MY GAIN UP, I HAD A TENDENCY TO OVERSHOOT. THE TRACKING WAS FAIR TO GOOD BUT NOT AS GOOD AS I WOULD LIKE TO SEE IT; I THINK I WOULD HAVE LIKED A MORE RESPONSIVE AIRPLANE. HOWEVER, FOR A MODERATELY LARGE AIRPLANE YOU PROBABLY DON'T WANT TO PUSH IT AROUND QUITE THAT FAST SO IT MIGHT JUST BE OKAY.	IN THE STEP ATT… SOME DIFFICULTY… THAT I COULD … ERRORS TO ZERO … OVERSHOOT. I F… PLANE SOMEWHAT … TIGHT CONTROL …
001	4.3	.61	2	1.5	THIS SEEMS TO BE A PRETTY GOOD AIRCRAFT. THE STICK FORCES AND SHORT PERIOD FREQUENCY SEEM TO MATCH WELL FOR THIS CLASS AIRCRAFT; HOWEVER, ON THE TRACKING TASKS THE AIRPLANE SEEMED TO HAVE A SOFT FEEL TO IT. I WOULD SAY THE STICK MOTIONS WERE MODERATE. I DID HAVE A SLIGHT TENDENCY TO OVERSHOOT DURING TRACKING, SO MY OVERALL IMPRESSION IS THAT IT'S A GOOD AIRCRAFT BUT IT COULD BE SLIGHTLY IMPROVED. I HAD NO PROBLEMS IN TURN ENTRY OR MAINTAINING LEVEL TURNS. NO PROBLEM IN CLIMBING OR DESCENDING TURNS. I HAD GOOD CONTROL OF RATE OF CLIMB AND DESCENT.	I THOUGHT THE STICK FORCES WERE QUITE GOOD. THEY MAY EVEN BE SLIGHTLY LIGHT SINCE THE PILOT HAS SOME TENDENCY TO OVERSHOOT WHEN HE'S TRACKING USING VERY HIGH GAINS. STICK DISPLACEMENTS ARE MODERATE.	41.1	THE AIRPLANE'S INITIAL AND FINAL RESPONSES ARE GOOD.	I HAD VERY GOOD PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL DURING ALL OF THE MANEUVERS. I COULD HOLD A DESIRED G OR CHANGE TO A NEW G LEVEL WITH NO PROBLEM.	I HAD A DEFINIT… IN THE TRACKING… ONLY OVERSHOOT … ONTO THE DESIR… DIFFICULTY. I … QUITE GOOD. THE… INDICATED A LIT… THE PILOT HAD … WOULD OVERSHOOT… INPUT AT ONE P… SHOOTING. THE … KEEP YOUR GAIN … THUS THE OVERS…

A

IXED $\frac{F_{EW}}{n_g}$ GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_z/\alpha \approx 16.5$ g/RAD, $\zeta_{sp} \approx 0.7$, V_T = 411 FT/SEC)

	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
...LE ...ING ... ...ING ...D	IN THE STEP TRACKING TASK, THE SLUGGISHNESS OF THE AIRPLANE MADE IT QUITE EASY TO OVERSHOOT AND OVERCONTROL. IN THE RANDOM INPUT TASK, I HAD EVEN MORE TENDENCY TO OVERDRIVE THE AIRPLANE. THERE JUST ISN'T THE PRECISION THAT YOU NEED FOR THE SMALL AMPLITUDE TRACKING TASKS.	THE RANDOM DISTURBANCES HAD NO EFFECT AT ALL ON MY PERFORMANCE, THE AIRPLANE RESPONDED ONLY SLIGHTLY TO THE DISTURBANCE.	GOOD PITCH DAMPING AND THE APPARENTLY MODERATE STICK FORCES WERE GOOD FEATURES.	THE SLUGGISHNESS IN THE INITIAL RESPONSE WAS OBJECTIONABLE.	I DO HAVE SOME PIO TENDENCY. I GET AN OVERSHOOT ANY TIME I ATTEMPT TIGHT CONTROL. I'LL RATE IT A 3 BECAUSE I'M NOT REALLY SURE THE PILOT CAN ELIMINATE THESE MOTIONS. I THINK THE AIRPLANE IS CONTROLLABLE, ACCEPTABLE, AND UNSATISFACTORY. IT'S DIFFICULT TO PREVENT OVERSHOOTING WHEN YOU'RE TRACKING. I'LL RATE IT AN A-4.
...RSHOOT ...LS. ...OVED YOU	THE CHARACTERISTICS THAT I HAVE DESCRIBED AS SLUGGISHNESS AND THE TENDENCY TO OVER DRIVE THE PITCH ATTITUDE AND NORMAL ACCELERATION WERE EXHIBITED IN THE STEP TRACKING TASK AND THE RANDOM INPUT TASK. I NEVER REALLY FELT AS THOUGH I HAD GOOD TIGHT ATTITUDE CONTROL.	THE AIRCRAFT DID NOT RESPOND VERY MUCH AT ALL TO THE RANDOM INPUTS. THE INPUTS DID MAKE THE ATTITUDE CONTROL SLIGHTLY MORE DIFFICULT BUT NOT ANY MORE SO THAN YOU WOULD EXPECT FROM NORMAL TURBULENCE.	THE AIRCRAFT HAS GOOD LONGITUDINAL SHORT PERIOD DAMPING AND THE STICK FORCE GRADIENT DID NOT SEEM TO BE VERY HEAVY.	THE TENDENCY TO OVERSHOOT, THE LACK OF PRECISION CONTROL OF PITCH ATTITUDE AND ACCELERATION, THE SLUGGISH RESPONSE OF THE AIRCRAFT AND THE SOFT FEEL YOU GET ARE ALL OBJECTIONABLE FEATURES.	IT WAS CERTAINLY EASY TO INDUCE PIO AND YOU HAD TO SACRIFICE PERFORMANCE TO ELIMINATE PIO. I THINK THE AIRPLANE IS CERTAINLY CONTROLLABLE. FOR THIS CLASS AIRPLANE I WOULD SAY IT'S ACCEPTABLE BUT NOT SATISFACTORY. IT HAS A MODERATELY OBJECTIONABLE DEFICIENCY IN THAT THE OVERALL TRACKING PERFORMANCE IS POOR I WOULD RATE IT AN A-5.
...NORMAL ...D	THE STEP INPUT TRACKING TASK WAS QUITE EASY AND I THINK MY PERFORMANCE WAS QUITE GOOD. THERE WAS A SLIGHT TENDENCY TO OVERCONTROL FOR VERY, VERY SMALL INPUTS. ON THE RANDOM INPUT TRACKING, I FOUND THAT I HAD TO CUT MY GAIN DOWN TO KEEP FROM OVERSHOOTING. I COULD STILL TRACK ACCURATELY BUT FOR VERY SMALL, ABRUPT INPUTS THERE WAS A TENDENCY TO BOBBLE.	I DON'T THINK THE AIRPLANE RESPONDED GREATLY TO THE RANDOM INPUTS. I FELT THAT MY ATTITUDE CONTROL WAS GOOD ENOUGH SO THAT I COULD PROBABLY DO IN-FLIGHT REFUELING.	THE AIRCRAFT WAS WELL DAMPED, THE MODERATE SHORT PERIOD FREQUENCY IS COMPATIBLE WITH THIS CLASS AIRCRAFT.	I HAVE A MILD OBJECTION TO THE SLIGHTLY HEAVY STEADY STATE STICK FORCES AND TO THIS SLIGHT TENDENCY TO BOBBLE FOR SMALL INPUTS.	I DON'T THINK I'LL EVER CONSIDER THAT BOBBLING TENDENCY IN THE PIO RATING. I'LL RATE IT A 1. FOR THE PILOT RATING I'M DEBATING HOW HEAVILY TO WEIGH THESE MINOR OBJECTIONS. I GUESS I'LL RATE IT AN A-1.5.
...ATION ...D EXPECTED. ...ITTLE ...ERROR ...UP, I HAD ...KING WAS ...I WOULD ...HAVE LIKED ...ED, FOR A ...ABLY ...E THAT	IN THE STEP ATTITUDE TRACKING TASK I HAD SOME DIFFICULTY IN ADJUSTING MY GAIN SO THAT I COULD REDUCE THE LARGE AMPLITUDE ERRORS TO ZERO AND AT THE SAME TIME NOT OVERSHOOT. I FELT I HAD TO PUSH THE AIRPLANE SOMEWHAT AND DIDN'T HAVE VERY TIGHT CONTROL OF THE TRACKING.	THE RANDOM DISTURBANCE DISTURBED THE AIRPLANE A LIGHT-TO-MODERATE AMOUNT. TRACKING IN THE PRESENCE OF THE RANDOM DISTURBANCE WAS A LITTLE MORE OF A PROBLEM BUT I CERTAINLY THINK IT WOULD BE ACCEPTABLE AND WOULD ALLOW ME TO TRACK PROPERLY.	I THINK THE STICK FORCES ARE COMFORTABLE, POSSIBLY A LITTLE LIGHT, BUT GOOD.	ALTHOUGH NOT A VERY LARGE OBJECTION, THE SLIGHT AMOUNT OF OVERSHOOTING TENDENCY WHICH I BELIEVE IS COUPLED WITH THE MODERATE SHORT PERIOD FREQUENCY WAS NOTICEABLE.	I HAVE TO ADMIT THERE IS SOME TENDENCY TO OVERSHOOT, HOWEVER, I CAN PREVENT THIS BY MERELY CUTTING DOWN MY GAIN. IN GENERAL IT IS A PRETTY GOOD AIRPLANE; IT'S CONTROLLABLE, ACCEPTABLE, A GOOD, PLEASANT WELL-BEHAVED AIRPLANE.
...D NORMAL OF THE ...D 6 OR PROBLEM.	I HAD A DEFINITE TENDENCY TO OVERSHOOT IN THE TRACKING TASKS; HOWEVER, I WOULD ONLY OVERSHOOT ONCE AND THEN LOCK RIGHT ONTO THE DESIRED ATTITUDE WITH NO REAL DIFFICULTY. I WOULD RATE THE TRACKING AS QUITE GOOD. THE RANDOM INPUT TRACKING INDICATED A LITTLE MORE GRAPHICALLY THAT THE PILOT HAD TO ADJUST HIS GAIN OR HE WOULD OVERSHOOT. I WAS ABLE TO SHAPE MY INPUT AT ONE POINT TO KEEP FROM OVERSHOOTING. THE GENERAL TENDENCY IS TO KEEP YOUR GAIN UP FAIRLY HIGH, HOWEVER, THUS THE OVERSHOOTING TENDENCY.	THE AIRCRAFT ONLY RESPONDED MODERATELY TO THE RANDOM DISTURBANCES. THERE WERE NO UNDESIRABLE CHARACTERISTICS THAT DETRACTED FROM MY TRACKING CAPABILITY ANY MORE THAN WOULD BE EXPECTED FROM NORMAL TURBULENCE.	THE AIRPLANE HAD GOOD DAMPING, GOOD RESPONSE, AND GOOD ACCELERATION CONTROL.	THE AIRPLANE'S SLIGHTLY SOFT FEELING IS THE ONLY OBJECTIONABLE FEATURE. I WOULD HAVE LIKED A LITTLE MORE PRECISE CONTROL.	THE AIRPLANE HAS A VERY SLIGHT TENDENCY FOR PIO. I'LL RATE IT A 1½. THE AIRCRAFT IS CONTROLLABLE, ACCEPTABLE, SATISFACTORY FOR THE MISSION AND IT IS CERTAINLY A GOOD, PLEASANT, WELL-BEHAVED AIRPLANE. I WOULD REQUEST A SLIGHT IMPROVEMENT IN THIS TENDENCY TO OVERSHOOT. I'LL RATE IT AN A-2.

TABLE IV-II (Continued) PILOT COMMENT SUMMARY, PILOT B, FIXED $\frac{f_{rw}}{n}$, GR

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PILOT B, FIXED $\frac{F_{EW}}{n_g}$ GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_g/\alpha \approx 16.5$ g/RAD, $\zeta_{SP} \approx 0.7$, V_T = 411 FT/SEC)

OL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
ACCELERATION OMEWHAT BY AN VER THIS Y GREAT	THERE WAS A DEFINITE TENDENCY TO OVERSHOOT THE DESIRED ATTITUDE DURING THE TRACKING TASKS. THE OVERSHOOTS TOOK A COUPLE OF CYCLES TO DAMP OUT BEFORE YOU COULD GET ESTABLISHED ON THE ATTITUDE.	MY TRACKING PERFORMANCE WAS DEFINITELY DETERIORATED BY THE RANDOM DISTURBANCES. EVEN THOUGH THE AMPLITUDE OF THE DISTURBANCES WAS SMALL IT WAS HARD TO MAKE THE TRACKING ERRORS SMALL BECAUSE THE FREQUENCY OF THE DISTURBANCES WAS JUST TOO FAST FOR THE PILOT TO KEEP UP WITH.	THE AIRPLANE IS WELL DAMPED. I LIKE THE INITIAL RESPONSE.	THE STEADY STATE STICK FORCES ARE A LITTLE ON THE HIGH SIDE. THERE WAS SOME TENDENCY TO BOBBLE THE AIRCRAFT.	THERE IS SOME PIO TENDENCY, BUT IT'S MINIMUM. THE AIRPLANE IS ACCEPTABLE AND SATISFACTORY. IT HAS SOME MILDLY UNPLEASANT CHARACTERISTICS.
ACCELERATION D.	DURING THE ATTITUDE TRACKING TASK I DID HAVE SOME TENDENCY TO OVERSHOOT THE G WHEN I HAD MY INPUT GAIN WAY UP. HOWEVER, I COULD STOP THE ATTITUDE CROSSBAR JUST ABOUT WHERE I WANTED IT. IF I DID OVERSHOOT, IT WAS VERY EASY TO MAKE THE CORRECTION TO BRING IT BACK TO ZERO. THE RANDOM NOISE TRACKING GAVE ME A LITTLE MORE TROUBLE BECAUSE WHEN MAKING SMALL AMPLITUDE ERROR CORRECTIONS I DID HAVE A TENDENCY TO BOBBLE.	IT WAS NOTICEABLY MORE DIFFICULT TO ESTABLISH A GIVEN ATTITUDE IN THE PRESENCE OF RANDOM DISTURBANCES. HOWEVER THE AIRPLANE DID NOT EXHIBIT ANY UNUSUAL CHARACTERISTICS OTHER THAN WHAT YOU MIGHT EXPECT IN NORMAL TURBULENCE.	THE AIRPLANE WAS PRETTY GOOD, RESPONSIVE, AND THE SHORT PERIOD DAMPING WAS GOOD. THE STICK FORCE GRADIENTS AND THE OVERALL FEEL SEEMED REASONABLE.	NO REAL OBJECTIONABLE FEATURES.	THERE'S A SLIGHT PIO TENDENCY. SOME UNDESIRABLE MOTION DOES OCCUR BUT CAN BE EASILY PREVENTED BY A REDUCTION IN PILOT GAIN. I'M GOING TO RATE IT A PIOR OF 1.5. THERE WERE JUST ENOUGH THINGS THAT I DIDN'T LIKE, PARTICULARLY IN THE TRACKING TASK AND IN THE RESPONSE IN TURBULENCE THAT I WILL RATE IT A AN A-2.5.
ACCELERATION DID HAVE OL SLIGHTLY.	MY TRACKING PERFORMANCE WAS FAIR. I HAD THE FEELING INITIALLY THAT I WOULD BOBBLE THE AIRPLANE, BUT THIS TENDENCY WAS AT A MINIMUM. THE BOBBLING TENDENCY DID SHOW UP A LITTLE MORE IN THE RANDOM INPUT TRACKING. I THINK THIS IS BECAUSE OF THE SMALL AMPLITUDE INPUTS AT HIGH PILOT GAINS.	THE RIDE IN THE PRESENCE OF RANDOM DISTURBANCES WAS A BIT CHOPPY. FOR SMALL DISTURBANCES THE AIRPLANE IS OKAY, BUT ITS PERFORMANCE IN THE PRESENCE OF LARGE DISTURBANCES COULD BE IMPROVED.	THE AIRPLANE IS WELL DAMPED AND HAS A GOOD INITIAL RESPONSE.	THE HEAVY FORCES ARE THE MOST OBJECTIONABLE FEATURE.	THERE WAS A SLIGHT TENDENCY FOR PIO TO OCCUR. I'LL GIVE IT A PIO RATING OF 1½. I'D SAY THE AIRCRAFT IS CONTROLLABLE, IT IS ACCEPTABLE AND THE ONLY QUESTION IS WHETHER IT IS SATISFACTORY OR UNSATISFACTORY BASED ON THE HEAVY STICK FORCES. I THINK THIS IS A MINOR BUT ANNOYING DEFICIENCY WITH IMPROVEMENT REQUESTED. I THINK I CAN DO THE MISSION BUT BECAUSE OF THE HEAVY FORCES I WOULD HAVE TO WORK VERY HARD. I'LL RATE IT AN A-4.

B

TABLE IV-III PILOT COMMENT SUMMARY, PILOT A, FIXED $\frac{F_{EW}}{n_g}$

FLIGHT NO.	ω_{SP} $\frac{RAD}{SEC}$	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_g}$ LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	
005	3.06	.70	7	2	THIS AIRPLANE IS REALLY NOT WHAT I'D LIKE TO SEE FOR THIS TYPE MISSION. IT'S A LITTLE SLUGGISH AND YOU HAVE A TENDENCY TO OVERCONTROL. YOU GET MORE G AND PITCH RATE THAN YOU WANT BECAUSE YOU HAVE TO PUT SUCH LARGE INPUTS IN TO GET THE NOSE MOVING INITIALLY.	THE STICK FORCES SEEMED TO LIGHTEN AFTER THE NOSE STARTED TO MOVE. ONCE THE AIRPLANE HAS SETTLED OUT AT SOME STEADY STATE G THE FORCES SEEM TO BE JUST A LITTLE LIGHT. I THINK WITH THESE FORCES YOU COULD INADVERTENTLY OVERSTRESS THE AIRPLANE. STICK DISPLACEMENTS WERE OKAY.	42.2	THE INITIAL RESPONSE TENDS TO BE A LITTLE SLUGGISH. THE FINAL RESPONSE IS GOOD AND STEADY.	NO COMMENTS	THERE WAS A TENDE[NCY] ... THE TRACKING TASK[S] ... AS I WOULD LIKE TO ... GETTING MORE G TH[AN] ... I WAS CHASING THE ...
003	4.11	.88	5	1	I DON'T PARTICULARLY LIKE IT BECAUSE IT'S A SLUGGISH AIRPLANE AND GENERALLY NOT AS FAST RESPONDING AS I'D LIKE TO SEE FOR THIS TYPE OF MISSION. IT APPEARS THAT THE g SORT OF LEADS THE PITCH RATE OR AT LEAST THE G PHASING IS DIFFERENT THAN YOU NORMALLY TEND TO SEE.	I THINK THE STICK FORCES ARE REASONABLE TO GIVE YOU STRUCTURAL PROTECTION. HOWEVER THEY TEND TO REDUCE YOUR RESPONSE SOMEWHAT BECAUSE OF THE SLUGGISH AIRPLANE.	72.0	THE INITIAL RESPONSE IS SLUGGISH. IT'S VERY STIFF FEELING. THERE IS NO OSCILLATORY TENDENCY AND THE FINAL RESPONSE IS SOLID ALL RIGHT. WHEN I WANT TO MAKE A RELATIVELY FAST INPUT THE AIRPLANE FEELS SLUGGISH BUT THEN WHEN IT STARTS MOVING THE g SORT OF COMES ON QUICKER THAN I EXPECT AND I END UP GETTING A LITTLE MORE THAN I WANTED. IT DOESN'T FEEL AS COMFORTABLE AS I WOULD LIKE.	ONCE THE AIRPLANE RESPONSE STARTS IT WANTS TO TAKE OFF FASTER THAN I EXPECT BUT IT DOES LIMIT ITSELF AND I CAN EASE INTO 2 g AND HOLD IT WITH RELATIVELY LITTLE DIFFICULTY. WHEN YOU'RE PULLING g THE INITIAL RESPONSE YOU GET LOOKS LIKE ITS SORT OF DIGGING IN A LITTLE. THE WAY THE PITCH ATTITUDE AND G BUILD UP JUST DOESN'T FEEL NICE FOR REAL PRECISE CONTROL IN TRACKING. IT'S MORE DIFFICULT FOR SMALL ATTITUDE CORRECTIONS THAN FOR HIGHER g MANUEVERS.	ALTHOUGH THE AIRPL[ANE] ... IN GETTING GOING ... REALLY GETTING IT ... IT WASN'T TOO DIFF[ICULT] ... THE NEEDLE DURING ...
001	5.58	.60	3	1	I HAVE NO REAL COMPLAINTS ABOUT THE AIRPLANE, BUT IT JUST DOESN'T FEEL AS GOOD AS I WOULD LIKE. THE THING I SEE IS THAT INITIALLY THE g SEEMS TO LEAD THE PITCH RATE. YOU SEEM TO GET G ON THE AIRPLANE BEFORE YOU REALIZE IT. WHEN TRYING TO CONTROL THE ATTITUDE YOU HAVE TO CHECK THE ELEVATOR TO HOLD THE NOSE WHERE YOU WANT IT. IN GENERAL YOU CAN TRACK PRETTY WELL WITH THE AIRPLANE. LONGITUDINAL CONTROL IN TURNS IS AFFECTED BY THIS FEELING THAT g LEADS THE PITCH RATE. ONCE YOU GET STABILIZED IN A TURN THE CONTROL FEELS GOOD.	THE INITIAL STICK FORCES SEEM RELATIVELY LIGHT. YOU GET ALMOST INSTANTANEOUS g RESPONSE WHEN YOU START TO PULL. AS YOU PULL INTO A HIGHER g, THE FORCES GET A LITTLE TOO HEAVY. INITIALLY THE FORCES JUST SEEM TO BE A LITTLE LIGHT FOR WHAT YOU WOULD EXPECT. STICK DISPLACEMENTS WERE GOOD.	42.8	THE INITIAL RESPONSE IS VERY QUICK. IT SEEMS TO COME ON WITH HARDLY ANY EFFORT. I GET THE FEELING THEN THAT THE g COMES ON FASTER THAN YOU WOULD EXPECT FOR A GIVEN AMOUNT OF ALTITUDE CHANGE.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL SEEM TO BE TWO DIFFERENT THINGS. ATTITUDE AND g INITIALLY SEEM TO BE TWO DIFFERENT RESPONSES. THE G COMES ON SO QUICKLY THAT YOU FEEL IT BEFORE YOU SEE THE ATTITUDE CHANGE VERY MUCH. IT SORT OF HELPS YOU INITIALLY IN TRACKING BECAUSE IT GIVES YOU A CLUE THAT THE AIRPLANE IS GOING TO START MOVING. HOWEVER TO STOP ON A TARGET YOU HAVE TO CHECK THE ELEVATOR. ONCE YOU'RE ON THE TARGET THE CONTROL SEEMS TO BE GOOD.	I'M NOT SURE WHETH[ER] ... IS HELPING OR HIND[ERING] ... TRACKING TASK. I D... CREASING MY PERFO[RMANCE] ... DOESN'T FEEL AS GO[OD] ...
003	6.04	.57	1	1	THIS AIRPLANE IS VERY GOOD ALL AROUND. I DON'T HAVE ANY COMPLAINTS OR ANYTHING I'VE SEEN. LONGITUDINAL CONTROL IN TURNS IS VERY GOOD. EVERYTHING IS JUST EASY TO DO. IT IS EASY TO MAKE ALTITUDE CHANGES AND STABILIZE ON THE NEW ALTITUDE.	THE FEEL SYSTEM IN GENERAL AND THE STICK FORCES IN PARTICULAR ARE VERY GOOD FOR A 3 g AIRPLANE.	35.3	AIRPLANE RESPONSE TO INPUTS IS VERY QUICK INITIALLY, BUT NOT SO QUICK THAT YOU WOULD OVERSTRESS THE AIRPLANE. THE FINAL RESPONSE IS VERY GOOD. YOU CAN STOP THE AIRPLANE ANYWHERE YOU WANT TO.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL IS GOOD. NO TENDENCY TO OVERCONTROL.	THE ATTITUDE TRACK[ING] ... IT WAS VERY EASY T[O] ... STAY ON THE NEEDLE.
007	10.4	.72	1	1	THIS IS REALLY ONE OF THE NICEST AIRPLANES I HAVE SEEN SO FAR. VERY PRECISE CONTROL, VERY WELL DAMPED. NO TENDENCY TO BOBBLE. THIS FEELS GOOD ALL THE WAY.	THE STICK FORCES WERE REASONABLE FOR A 3 G AIRPLANE. THE SPRING RATE WAS NOT DETRIMENTAL AND MY OPINION OF THE AIRPLANE WAS NOT REDUCED BY ANY UNUSUAL STICK DISPLACEMENTS.	44.8	THE INITIAL RESPONSE IS VERY PRECISE. YOU GET THE RATE OF CHANGE OF ATTITUDE IN THE g ONSET THAT IS SO NATURAL IT MAKES THE AIRPLANE FEEL LIKE IT IS ALMOST AN EXTENSION OF THE PILOT. THE FINAL RESPONSE IS EQUALLY GOOD. YOU HAVE THE ABILITY TO STOP WHERE YOU WANT AND YOU CAN ALMOST THINK OF WHAT YOU WANT AND YOU HAVE IT.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WERE JUST VERY EXCELLENT. FOR NORMAL ACCELERATION CONTROL THERE IS NO TENDENCY TO BOBBLE. YOU FEEL THE g COMING ON VERY QUICKLY. YOU DON'T HAVE TO WAIT FOR THE AIRPLANE TO ROTATE. THE G TENDS TO ALMOST LEAD THE PITCH ATTITUDE CHANGE.	TRACKING CAPABILITY ... ATTITUDE TRACKING ... I DON'T THINK YOU C...
005	14.2	.65	5	1	I LIKED THE AIRPLANE FOR TRACKING. THE STICK FORCE PER g IS TOO HIGH HOWEVER.	THE STEADY STATE STICK FORCE PER g IS TOO HIGH. THERE WERE NO NOTICEABLE STICK DISPLACEMENTS.	44.7	FOR LARGE MANUEVERS THE AIRPLANE FELT HEAVY AND SLUGGISH. FOR SMALL CORRECTIONS IT FEELS VERY NICE. THE RESPONSE IS GOOD. IT FEELS NICE AND SOLID. YOU CAN JUST PITCH UP TO WHERE YOU WANT AND STOP IT. THERE IS NO TENDENCY TO BOBBLE.	IT FEELS HEAVY AND TRUCK LIKE FOR LARGE MANUEVERS. FOR THE SMALL INPUTS IT SEEMS VERY GOOD.	FOR SMALL CORRECTI[ONS] ... TASKS IT WASN'T ... RECTIONS THE AIRPL[ANE] ... SLUGGISH

A

ILOT A, FIXED $\frac{F_{ES}}{n_z}$ GROUP II ($1/T_{\theta_2} \approx 2.65$, $n_z/\alpha \approx 56.2$ g/RAD, $\zeta_{sp} \approx 0.7$, V_T = 685 FT/SEC)

TUDE AL CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
	THERE WAS A TENDENCY TO OVERCONTROL IN THE TRACKING TASKS. I WASN'T AS PRECISE AS I WOULD LIKE TO HAVE BEEN. I WAS GETTING MORE G THAN I HAD EXPECTED WHEN I WAS CHASING THE NEEDLE	NO COMMENTS.	IN SLOW, EASY MANEUVERING THE AIRPLANE IS STABLE ALL THE WAY.	THE AIRPLANE HAS A SLUGGISH INITIAL RESPONSE. THERE IS A TENDENCY TO OVERCONTROL OR OVER-g THE AIRPLANE.	THERE ARE UNDESIRABLE MOTIONS WHEN YOU INITIATE ABRUPT MANEUVERS. THEY CAN BE PREVENTED BY SLACKING OFF ON THE CONTROLS. FOR THE MISSION, THIS AIRPLANE IS UNACCEPTABLE. I THINK YOU COULD INADVERTENTLY OVERSTRESS IT. THIS WOULD HAVE TO BE FIXED. I WILL RATE IT A U-7.
RESPONSE STARTS, IT FASTER THAN I EXPECT TSELF AND I CAN EASE T WITH RELATIVELY WHEN YOU'RE PULLING G E YOU GET LOOKS LIKE S IN A LITTLE. THE WAY AND G BUILD UP JUST FOR REAL PRECISE CON- IT'S MORE DIFFICULT CORRECTIONS THAN FOR .	ALTHOUGH THE AIRPLANE IS FAIRLY SLUGGISH IN GETTING GOING AND IS JUST TOO SLOW IN REALLY GETTING IT TO DO SOMETHING FAST, IT WASN'T TOO DIFFICULT TO STAY WITH THE NEEDLE DURING THE TRACKING TASKS.	THE RANDOM DISTURBANCE INPUT DIDN'T SEEM TO AFFECT THE AIRPLANE VERY MUCH AND OF COURSE WITH A LOW FREQUENCY AIRPLANE YOU WOULD NOT EXPECT THE AIRPLANE TO BE DISTURBED VERY MUCH BY HIGHER FREQUENCY DISTURBANCES.	THE GOOD FEATURES WERE THE FACT THAT IT WAS REALLY SOLID ONCE YOU GOT TO WHERE YOU WANTED TO BE WITH NO OSCILLATORY TENDENCY.	THE OBJECTIONABLE FEATURES ARE THAT IT IS A VERY STIFF-FEELING AIRPLANE. IT'S VERY SLUGGISH FEELING INITIALLY EXCEPT YOU GET A SORT OF DIGGING-IN TENDENCY WHERE THE G TENDS TO SORT OF LEAD THE PITCH ATTITUDE. FOR SMALLER, TIGHTER CORRECTIONS THE PILOT DOESN'T HAVE A VERY PRECISE FEELING OF WHERE HE CAN STOP THE AIRPLANE.	THERE IS NO TENDENCY FOR THE PILOT TO INDUCE UNDESIRABLE MOTIONS. THE AIRPLANE IS CERTAINLY NOT SATISFACTORY. I WOULD LIKE TO SEE THIS DIGGING-IN TENDENCY FIXED. I FEEL I COULD DO THE MISSION BUT IT IS RELUCTANTLY ACCEPTABLE. THE G LEADING WITH PITCH IS SOMETHING THAT'S A LITTLE BIT LESS ACCEPTABLE THAN JUST HAVING THE LOW FREQUENCY SLUGGISH AIRPLANE.
D NORMAL ACCELERATION E TWO DIFFERENT THINGS ITIALLY SEEM TO BE TWO ES. THE G COMES ON SO FEEL IT BEFORE YOU SEE E VERY MUCH. IT SORT IALLY IN TRACKING YOU A CLUE THAT THE TO START MOVING. A TARGET YOU HAVE TO . ONCE YOU'RE ON TROL SEEMS TO BE GOOD	I'M NOT SURE WHETHER THE INITIAL G ONSET IS HELPING OR HINDERING ME IN THE TRACKING TASK. I DON'T THINK IT WAS DECREASING MY PERFORMANCE BUT IT JUST DOESN'T FEEL AS GOOD AS I WOULD LIKE	NO COMMENTS.	THE GOOD FEATURES WERE THAT THERE WAS NO TENDENCY TO BOBBLE AROUND ON A TARGET AND YOU COULD MAINTAIN TIGHT CONTROL IN THE STEADY STATE.	I THINK THE FEELING THAT THE ATTITUDE AND G RESPONSES ARE SEPARATE RESPONSES INITIALLY IS OBJECTIONABLE.	THERE WAS NO TENDENCY TO INTRODUCE UNDESIRABLE MOTIONS. I THINK THE AIRPLANE IS SATISFACTORY. I DON'T THINK THAT ANYTHING HAS TO BE FIXED BUT THE G ONSET IS MILDLY UNPLEASANT. I WOULD RATE IT AN A-3.
NORMAL ACCELERATION TENDENCY TO OVER-	THE ATTITUDE TRACKING TASK WAS EASY TO DO IT WAS VERY EASY TO MAKE CORRECTIONS TO STAY ON THE NEEDLE	NO COMMENTS	EVERYTHING WAS GOOD. NICE, FAST RESPONDING AIRPLANE WITH NO TENDENCY TO OVERSHOOT OR OVER-g THE AIRPLANE JUST FEELS GOOD ALL AROUND.	NONE.	I THINK THE AIRPLANE IS GREAT FOR THE MISSION.
NORMAL ACCELERATION VERY EXCELLENT. FOR CONTROL THERE IS NO . YOU FEEL THE g ALLY. YOU DON'T HAVE PLANE TO ROTATE T LEAD THE PITCH	TRACKING CAPABILITY IS EXCELLENT. THE ATTITUDE TRACKING TASK WAS REALLY GOOD. I DON'T THINK YOU COULD DO ANY BETTER.	IN THE PRESENCE OF THE RANDOM DISTURBANCES THE AIRPLANE BOBBLED AROUND QUITE A BIT. ALTHOUGH YOUR FIRING PERFORMANCE WOULD BE DEGRADED THE ATTITUDE EXCURSIONS WERE NOT REALLY BIG. IT IS DIFFICULT TO SMOOTH OUT THE DISTURBANCE INPUTS	EVERYTHING ABOUT THIS CONFIGURATION WAS GOOD. GREAT TRACKING, GOOD ATTITUDE CONTROL. SMOOTH RESPONSE ENTRIES FOR TRACKING AND HOLDING G. PRECISE CONTROL, NO TENDENCY TO BOBBLE. JUST GOOD ALL AROUND.	NO OBJECTIONABLE FEATURES THAT I CAN SEE.	FOR THE MISSION AS I VISUALIZE IT, THE AIRPLANE IS VERY PRECISE. JUST GOOD ALL AROUND.
TRUCK-LIKE FOR THE SMALL INPUTS .	FOR SMALL CORRECTIONS IN THE TRACKING TASKS IT WASN'T BAD. FOR THE LARGE CORRECTIONS THE AIRPLANE FEELS HEAVY AND SLUGGISH	THE RANDOM DISTURBANCES DIDN'T REALLY HAVE MUCH EFFECT ON THE AIRPLANE	IT IS A REAL SOLID FEELING AIRPLANE. WHEN YOU ARE MAKING SMALL CORRECTIONS IT IS PRECISE AND STABLE	IT FEELS LIKE A TRUCK IN THE LARGE AMPLITUDE MANEUVERS	NO TENDENCY TOWARDS PIO AT ALL. I HAVE TO DOWN RATE THE AIRPLANE BECAUSE OF THE SLUGGISHNESS IN LARGE AMPLITUDE MANEUVERS. THE HEAVY FORCES ARE MODERATELY OBJECTIONABLE AND I WOULD LIKE TO SEE THEM IMPROVED

B

TABLE IV-IV PILOT COMMENT SUMMARY, PILOT B, FIXED $\frac{F_{SW}}{n_z}$ GROUP

FLIGHT NO.	ω_{SP} RAD/SEC	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{SW}}{n_z}$ LB/G	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
001	3.00	0.61	6.5	1.5	MY INITIAL IMPRESSION OF THIS AIRCRAFT IS THAT IT FEELS VERY HEAVY AND IS NOT VERY GOOD. THE FORCES ARE TOO HEAVY AND THE INITIAL RESPONSE IS TOO SLUGGISH FOR THIS CLASS AIRCRAFT. I HAD SOME DIFFICULTY TRIMMING. I HAD DIFFICULTY ESTABLISHING ZERO RATE OF CLIMB AT THE PROPER AIRSPEED. THIS, ALONG WITH HAVING TO CHANGE POWER SETTINGS, MADE THE TRIMMING SOMEWHAT DIFFICULT. AFTER WORKING AT IT, HOWEVER, I COULD GET THE AIRPLANE IN GOOD TRIM. TO OBTAIN A NEW ALTITUDE I HAD TO ANTICIPATE LEVEL-OFF AND LEAD IT QUITE A BIT WITH MY INPUTS. I COULD DO FAIRLY DECENT LEVEL TURNS, BUT THE CONTROLS FELT VERY HEAVY. CLIMBING AND DESCENDING TURNS WERE NOT TOO BAD, BUT IT TOOK A CONSIDERABLE AMOUNT OF TIME TO REACH THE DESIRED CONDITION. I HAD TO DO QUITE A BIT OF POWER MANIPULATING WITH THIS AIRCRAFT. WITH THIS SLUGGISH LONGITUDINAL CONTROL I ALSO GOT THE FEELING THAT THE LATERAL-DIRECTIONAL CONTROL WAS SLUGGISH. I THINK THIS WAS DUE TO MY FATIGUE FROM WORKING SO HARD TO CONTROL THE AIRCRAFT.	THE STICK FORCES ARE MUCH TOO HEAVY. THE FORCES REQUIRED TO MANEUVER SEEMED TO BE WORSE THAN THOSE REQUIRED TO MAINTAIN A STEADY STATE. THE STICK DISPLACEMENTS SEEMED TO BE LARGE, BUT I THINK THIS IS DUE TO MY TRYING TO FORCE THE AIRPLANE TO RESPOND MORE QUICKLY THAN ITS DYNAMICS WILL ALLOW.	62.0	THE INITIAL ACCELERATION AND PITCH RESPONSE IS QUITE POOR. THE INITIAL RESPONSE IS MUCH TOO SLUGGISH. I AM ABLE TO MAINTAIN A GOOD STEADY STATE g IN THE FINAL RESPONSE BUT THE AIRCRAFT FEELS VERY HEAVY.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WAS GOOD IN THE SENSE THAT YOU COULD MAINTAIN A DESIRED ATTITUDE OR ACCELERATION; HOWEVER, DUE TO THE SLUGGISH RESPONSE IT TAKES A RELATIVELY LONG TIME TO REACH THE DESIRED ATTITUDE OR ACCELERATION. ALSO, IT WAS DIFFICULT TO MAKE SMALL CORRECTIONS AND TOOK CONSIDERABLE PILOT ATTENTION.	IT WAS DIFFICULT TO MOVE THE NO[illegible] TO DO A DECENT JOB OF TRACKING. [illegible] STEP TRACKING TASK THERE WAS VE[illegible] TENDENCY TO OVERSHOOT, BUT IT T[illegible] CONSIDERABLE TIME TO GET THE AI[illegible] RESPOND. I JUST FELT THE TIME [illegible] IN CANCELLING OUT THE PITCH ATTI[illegible] ERROR WAS TOO LONG. THE RANDOM [illegible] TRACKING WAS VERY TIRESOME BECA[illegible] SMALL CONTINUOUS CORRECTIONS THAT [illegible] BE MADE.
[illegible]	3.04	0.83	5	2	THIS IS NOT A VERY DESIRABLE CONFIGURATION PRIMARILY BECAUSE OF ITS HIGH STICK FORCES AND SLUGGISH RESPONSE.	STICK FORCES WERE TOO HEAVY AND THE STICK DISPLACEMENTS WERE OKAY.	64.6	THE INITIAL RESPONSE IS VERY, VERY SLOW. THE FINAL RESPONSE WASN'T TOO BAD.	I HAD A TENDENCY TO OVERCONTROL WHILE TRACKING. IT SEEMED I TRIED TO FORCE THE INITIAL RESPONSE BY APPLYING MUCH LARGER THAN NORMAL FORCES. WHEN THE AIRPLANE FINALLY REACTED IT SEEMED AS THOUGH THE ACCELERATION BUILD UP WAS MUCH FASTER THAN I HAD ANTICIPATED.	THERE WAS A TENDENCY TO OVERDRI[illegible] AIRPLANE, ESPECIALLY IN THE RA[illegible] TASK.
[illegible]	4.3	0.69	5.5	1	I DIDN'T LIKE THIS CONFIGURATION PRIMARILY FOR ONE REASON: THE SLUGGISH RESPONSE AND HEAVY STICK FORCES OR A COMBINATION OF THESE TWO THINGS GAVE THE OVERALL IMPRESSION THAT THE AIRPLANE WAS JUST TOO HARD TO MOVE AROUND. I DIDN'T HAVE ANY PARTICULAR DIFFICULTY TRIMMING. IT DID TAKE ME A LITTLE LONGER THAN NORMAL TO TRIM SO I WOULD SAY THE TRIMABILITY WAS ONLY FAIR. ALTITUDE CONTROL WASN'T TOO BAD. I HAD SOME TROUBLE ENTERING TURNS AND HOLDING THE DESIRED g IN TURNS.	THE STICK FORCES FELT MUCH TOO HIGH. THE STICK MOTIONS DIDN'T SEEM EXCESSIVE, BUT THE STICK WAS CERTAINLY MOVING. I COULD PULL 2 g'S INCREMENTAL BUT ONLY BY HOLDING A FAIR AMOUNT OF FORCE. IN A TURN THE FORCES REQUIRED TO HOLD 2 g'S WERE NOTICEABLY OBJECTIONABLE.	53.3	I THOUGHT THE AIRPLANE'S INITIAL RESPONSE TO THE PILOT'S INPUTS WAS TOO SLOW. I HAD DIFFICULTY DURING THE FINAL RESPONSE IN OBTAINING AND MAINTAINING A GIVEN ACCELERATION. SINCE I DID HAVE TROUBLE MAKING LEVEL TURNS AND MAINTAINING A GIVEN g LEVEL, I DID NOT LIKE THE INITIAL AND FINAL RESPONSE.	I DID NOT THINK MUCH OF THE PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL. IT WAS HARD TO OBTAIN AND MAINTAIN AN ATTITUDE OR ACCELERATION AS FAST AS YOU MIGHT LIKE BECAUSE OF THE AIRCRAFT'S SLUGGISH RESPONSE.	THERE WAS CERTAINLY NO OVERSHOOT ON THE TRACKING TASKS. I COUL[illegible] THE AIRPLANE AS FAST AS I WOULD [illegible] WASN'T ABLE TO NULL OUT THE ERR[illegible] ENOUGH.
[illegible]	5.7	.54	4.5	2	I DIDN'T PARTICULARLY LIKE THIS CONFIGURATION. I THINK THE MAIN REASONS FOR THIS ARE THE STICK FORCES AND/OR MOTIONS. I THOUGHT IT WAS JUST A SLUGGISH AIRPLANE, BUT LOOKING AT THE THING OPEN-LOOP I SEE THAT IT'S APPARENTLY FAIRLY HIGH FREQUENCY. SO I GUESS WHAT GAVE ME THE IMPRESSION OF SLUGGISHNESS WAS THE STICK FORCES AND DISPLACEMENTS. I HAD A LITTLE DIFFICULTY TRIMMING THE AIRCRAFT. THIS MAY HAVE BEEN DUE TO THE T-33'S NOSE LOW ATTITUDE AT HIGH SPEED. IT IS HARD TO GET USED TO SEEING THE NOSE THAT LOW. I ALSO HAD SOME DIFFICULTY IN ALTITUDE CONTROL, BUT AGAIN THIS MAY HAVE BEEN DUE TO THIS NOSE LOW ATTITUDE. I HAD SOME SLIGHT DIFFICULTY IN MAKING LEVEL TURNS. I WOULD SAY THE LONGITUDINAL CONTROL IN TURNS WAS ONLY FAIR.	THE STICK FORCES ARE ON THE HIGH SIDE. AT 2 G INCREMENTAL, I FELT THE STICK FORCES WERE QUITE HEAVY AND THE STICK DISPLACEMENTS QUITE LARGE. THE SYMMETRICAL PULL-UPS DIDN'T SEEM TOO BAD. SMALL AMPLITUDE CHANGES DIDN'T SEEM QUITE AS BAD EITHER, BUT FOR LARGE AMPLITUDE ATTITUDE CHANGES, I THOUGHT THE FORCES WERE ON THE HEAVY SIDE.	33.9	I GOT THE FEELING THAT THE AIRPLANE RESPONSE WAS A LITTLE SLUGGISH, BUT I DON'T THINK IT WAS THE AIRPLANE'S DYNAMICS. I THINK IT WAS CONTROL FEEL THAT GAVE ME THE IMPRESSION THAT THE INITIAL RESPONSE WAS SLOW. THE FINAL RESPONSE WAS PRETTY GOOD, ALTHOUGH I DID HAVE SOME SLIGHT TENDENCY TO BOBBLE WHEN TRYING TO HOLD A STEADY STATE G. I THINK I WAS PROBABLY RELAXING MY BACK PRESSURE UNLESS I CONSCIOUSLY THOUGHT ABOUT IT AND HELD IT IN THERE. THUS IT SEEMED THE G WANDERED A LITTLE BUT NOT TOO BAD.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WAS ONLY FAIR BECAUSE I FELT I COULD NOT PUT THE NOSE WHERE I WANTED IT FAST ENOUGH.	THE STEP INPUT TRACKING WAS NOT [illegible] OVERALL, HOWEVER [illegible] THOUGHT [illegible] CONTROLLING A FAIR AMOUNT [illegible] ZERO THE ERROR [illegible] HAD THE FEEL[illegible] I WAS BEING TOO ABRUPT WITH THE [illegible] THE RANDOM INPUT TASK WAS MORE [illegible] CHALLENGE [illegible] GAVE THE BACK SEAT [illegible] FAIRLY ROUGH [illegible] AND [illegible] HAD SOM[illegible] TO BOBBLE [illegible] MADE MY INPUTS IN [illegible] PHASES [illegible] LARGE ABRUPT INPUT AND THEN I C[illegible] DOWN AND [illegible] THE NEED[illegible] THIS WAS A [illegible] TASK [illegible] THINK MY GAIN WAS A FUNCTION OF [illegible] AMPLITUDE OF THE RANDOM INPUTS.
007	6.5	.53	3.5	2	I WOULD CALL THIS A FAIR CONFIGURATION. THIS IS A RESPONSIVE AIRPLANE. THE FREQUENCY SEEMS HIGH AND THE DAMPING GOOD. THE FEEL OF THE AIRPLANE IS WHERE I HAD TROUBLE. MY OVERALL IMPRESSION WAS THAT THE STICK FORCES COULD HAVE BEEN A LITTLE LIGHTER. MY ABILITY TO TRIM WAS ONLY FAIR. I HAD TO MAKE A NUMBER OF SMALL INPUTS ON THE TRIM TO REACH A STEADY STATE, BUT ONCE THE TRIM POSITION WAS ESTABLISHED, THE AIRPLANE MAINTAINED IT VERY WELL. NO PARTICULAR PROBLEM WITH ALTITUDE CONTROL. I HAD SOME DIFFICULTY WITH LONGITUDINAL CONTROL IN TURNS, BUT I BELIEVE IT WAS MOSTLY DUE TO THE FACT THAT IT IS MUCH HARDER TO MAINTAIN A GIVEN AIRSPEED AT THIS HIGH SPEED. THE ENTRY AND RECOVERY FROM TURNS WAS OKAY. CLIMBING AND DESCENDING TURNS, AGAIN, I HAD SOME DIFFICULTY WITH PRECISION CONTROL, BUT IT WAS FAIR.	STICK FORCES ARE NOT TOO BAD. I COULD PULL 2 INCREMENTAL G'S REASONABLY WELL. I'D SAY FOR THIS CLASS AIRPLANE THE FORCES ARE FAIR. THERE WAS A LITTLE TENDENCY TO BE ABRUPT WITH INITIAL INPUTS, ESPECIALLY IN THE NEGATIVE G DIRECTION. MAYBE THE STICK FORCES ARE A LITTLE LIGHT FOR SMALL AMPLITUDE MANEUVERS AND MAYBE A LITTLE HEAVY FOR THE LARGER AMPLITUDE MANEUVERS. STICK DISPLACEMENTS I'D SAY ARE MODERATE.	48.0	INITIAL RESPONSE TO PILOT INPUTS IS A LITTLE ABRUPT FOR LARGE AMPLITUDE MANEUVERS. FINAL RESPONSE SEEMED OKAY.	I DID HAVE A TENDENCY TO OVERSHOOT WHEN TRACKING. THE AMPLITUDE OF THE OVERSHOOT DIDN'T SEEM TO BE VERY LARGE AT ALL. I WOULD CALL THE TRACKING CAPABILITY OF THIS AIRCRAFT FAIR TO GOOD.	DURING THE STEP INPUT TRACKING [illegible] TO DO A LOT OF POWER MANIPULATI[illegible] CONSEQUENTLY I HAVE TO FLY WIT[illegible] MOST OF THE TIME AND FOR THE LA[illegible] RECTIONS I JUST DON'T HAVE ENOU[illegible] WITH ONE HAND TO PUT IN THE NEC[illegible] ELEVATOR. VERY OFTEN THE CORREC[illegible] WERE MADE IN STEPS [illegible] PUT IN [illegible] SIDER TO BE A FAIRLY LARGE INPU[illegible] I FIND THAT I WAS NOT QUITE THERE [illegible] IN ANOTHER. THIS SECOND INPUT [illegible] CAUSES ME TO OVERSHOOT. THIS O[illegible] TENDENCY WAS PARTICULARLY TRUE [illegible] NEGATIVE G DIRECTION [illegible] VERY [illegible] TO PUT IN LARGE NEGATIVE G INPU[illegible] OF THIS OVERSHOOT TENDENCY. IF [illegible] WITH TWO HANDS I HAVE [illegible] BETT[illegible] I STILL HAVE A TENDENCY TO OVERS[illegible] WITH THE LARGE INPUTS AND OVERS[illegible] THE SMALL INPUTS. I WOULD SAY [illegible] SHOOT TENDENCY IN THE RANDOM I[illegible] TRACKING TASKS WAS MILD. THE [illegible] BOTHERED ME MOST WAS THE ABRUPT[illegible] INITIAL RESPONSE RATHER THAN THE [illegible] TENDENCY.

LOT B, FIXED $\frac{F_{sw}}{\theta}$ GROUP II ($1/T_{\theta_2} \approx 2.65$, $n/\alpha \approx 56.2$ g/RAD, $\zeta_{sp} \approx 0.7$, V_T = 585 FT/SEC)

...ITUDE ...MAL ... CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
...RMAL ACCELERATION ...THE SENSE THAT YOU ...IRED ATTITUDE ...EVER, DUE TO THE ...THERE A RELATIVELY ...HE DESIRED ATTITUDE ...), IT WAS DIFFICULT ...TIONS AND TOOK CON-...TION.	IT WAS DIFFICULT TO MOVE THE NOSE AROUND TO DO A DECENT JOB OF TRACKING. IN THE STEP TRACKING TASK THERE WAS VERY LITTLE TENDENCY TO OVERSHOOT, BUT IT TOOK A CONSIDERABLE TIME TO GET THE AIRPLANE TO RESPOND. I JUST FELT THE TIME ELEMENT IN CANCELLING OUT THE PITCH ATTITUDE ERROR WAS TOO LONG. THE RANDOM INPUT TRACKING WAS VERY TIRESOME BECAUSE OF THE SMALL CONTINUOUS CORRECTIONS THAT HAD TO BE MADE.	NO COMMENTS	THE AIRCRAFT IS CERTAINLY WELL DAMPED.	THE MOST OBJECTIONABLE FEATURE IS THE HEAVY STICK FORCE. ALSO, THE FACT THAT I COULDN'T TELL WHETHER OR NOT THE AIRPLANE HAD RETURNED TO ITS TRIM CONDITION WAS OBJECTIONABLE. THE AIRPLANE'S RESPONSE IS TOO SLUGGISH.	I DID OCCASIONALLY SEE A SLIGHT PIO TENDENCY. I WILL RATE IT A PIOR OF 1 1/2. THE AIRPLANE IS CONTROLLABLE. THE STICK FORCES ARE TOO HEAVY AND THE RESPONSE TOO SLUGGISH, SO MINIMUM ACCEPTABLE IS TOO [illegible]. I'M GOING TO RATE IT AN A-6.5.
...OVERCONTROL WHILE ...I TRIED TO FORCE THE ...APPLYING MUCH LARGER ...WHEN THE AIRPLANE ...EEMED AS THOUGH THE ...P WAS MUCH FASTER ...ED.	THERE WAS A TENDENCY TO OVERDRIVE THE AIRPLANE, ESPECIALLY IN THE RANDOM INPUT TASK.	THE PRESENCE OF RANDOM DISTURBANCES SEEMS TO ACCENTUATE THE TENDENCY TO OVER CONTROL WHILE TRACKING, BUT THE AIRPLANE'S ACTUAL RESPONSE TO THE DISTURBANCES DOESN'T SEEM TO BE TOO LARGE AT ALL.	THE AIRPLANE HAS GOOD DAMPING OF THE SHORT PERIOD.	THE OBJECTIONABLE FEATURES ARE PRIMARILY THE SLUGGISH RESPONSE AND THE HEAVY STICK FORCES.	THERE IS A MILD PIO TENDENCY. THE AIRPLANE IS CONTROLLABLE, ACCEPTABLE, BUT CERTAINLY UNSATISFACTORY. I THINK YOU JUST HAVE TO WORK TOO HARD TO FLY THE AIRPLANE.
...OF THE PITCH ... ...ERATION CONTROL ...I AND MAINTAIN AN ...TION AS FAST AS YOU ...THE AIRCRAFT'S	THERE WAS CERTAINLY NO OVERSHOOT TENDENCY ON THE TRACKING TASKS. I COULDN'T DRIVE THE AIRPLANE AS FAST AS I WOULD LIKE. I WASN'T ABLE TO NULL OUT THE ERRORS FAST [illegible].	CONTROL IN THE PRESENCE OF RANDOM DISTURBANCES WASN'T TOO BAD, BUT IT SEEMED AS THOUGH EVERYTHING HAD TO BE DONE IN SLOW MOTION.	THE GOOD DAMPING IN PITCH AND THE FACT THAT THERE WAS NO PIO TENDENCY COULD BE CONSIDERED GOOD FEATURES.	OBJECTIONABLE FEATURES INCLUDE THE SLUGGISH OPEN LOOP RESPONSE AND HEAVY STICK FORCES WHICH COMBINE TO GIVE THE OVERALL IMPRESSION THAT THE AIRPLANE IS NOT SUFFICIENTLY RESPONSIVE TO PILOT INPUTS.	THERE WAS NO PIO TENDENCY. I THINK THAT THE AIRPLANE IS CONTROLLABLE, BUT IT NEEDS MAJOR IMPROVEMENT. ONE THING THAT DOWNGRADES THIS AIRPLANE IS THE FACT THAT I DON'T THINK I COULD MANEUVER THE AIRPLANE TO ITS MAXIMUM ACCELERATION LIMITS WITHOUT A GREAT DEAL OF EFFORT. I THINK THIS IS BETWEEN MODERATELY AND VERY OBJECTIONABLE SO I'LL RATE IT AN A-5.5.
...RMAL ACCELERATION ...BECAUSE I FELT I ...E WHERE I WANTED	THE STEP INPUT TRACKING WAS NOT TOO BAD OVERALL; HOWEVER I THOUGHT I WAS OVER-CONTROLLING A FAIR AMOUNT IN TRYING TO ZERO THE ERROR. I HAD THE FEELING THAT I WAS BEING TOO ABRUPT WITH THE AIRPLANE. THE RANDOM INPUT TASK WAS MORE OF A CHALLENGE. I GAVE THE BACK SEAT PILOT A FAIRLY ROUGH RIDE AND I HAD SOME TENDENCY TO BOBBLE. I MADE MY INPUTS IN TWO PHASES. THE INITIAL REACTION WAS A RATHER LARGE ABRUPT INPUT AND THEN I CUT MY GAIN DOWN AND TRIED TO [illegible] THE NEEDLE TO ZERO. THIS WAS A CONTINUOUS TASK THOUGH, SO I THINK MY GAIN WAS A FUNCTION OF THE AMPLITUDE OF THE RANDOM INPUTS.	THE RIDING QUALITY IN THE PRESENCE OF RANDOM DISTURBANCES WAS NOTICEABLY LESS FAVORABLE THAN SOME CONFIGURATIONS. I BELIEVE THE PILOT TASK WOULD BE CONSIDERABLY MORE DIFFICULT IN SUCH AREAS AS REFUELING.	THE SHORT PERIOD IS FAIRLY WELL DAMPED AND THE FREQUENCY IS FAIRLY GOOD. THE AIRPLANE IS FAIRLY RESPONSIVE.	I OBJECT TO THE STICK FORCES AND MOTIONS.	WE CAN ELIMINATE ANY PIO TENDENCY BY REDUCING THE GAIN. I'LL RATE THIS A 2. I THINK THE AIRPLANE IS SOMEWHAT UNSATISFACTORY ON THE BASIS OF THE STICK FORCES AND STICK DISPLACEMENTS. I WOULD CALL THESE MODERATELY OBJECTIONABLE DEFICIENCIES. I'LL RATE IT A 4 1/2.
...TO OVERSHOOT ...PLITUDE OF THE ...TO BE VERY ...CALL THE TRACKING ...RCRAFT FAIR TO	DURING THE STEP INPUT TRACKING I HAD TO DO A LOT OF POWER MANIPULATION. CONSEQUENTLY, I HAVE TO FLY WITH ONE HAND MOST OF THE TIME AND FOR THE LARGE CORRECTIONS I JUST DON'T HAVE ENOUGH POWER WITH ONE HAND TO PUT IN THE NECESSARY ELEVATOR. VERY OFTEN THE CORRECTIONS WERE MADE IN STEPS. I PUT IN WHAT I CONSIDER TO BE A FAIRLY LARGE INPUT AND THEN I FIND THAT I'M NOT QUITE THERE SO I PUT IN ANOTHER. THIS SECOND INPUT USUALLY CAUSES ME TO OVERSHOOT. THIS OVERSHOOT TENDENCY WAS PARTICULARLY TRUE IN THE NEGATIVE G DIRECTION. I'M VERY HESITANT TO PUT IN LARGE NEGATIVE G INPUTS BECAUSE OF THIS OVERSHOOT TENDENCY. IF I FLY WITH TWO HANDS I HAVE MUCH BETTER SUCCESS. I STILL HAVE A TENDENCY TO UNDERSHOOT WITH THE LARGE INPUTS AND OVERSHOOT WITH THE SMALL INPUTS. I WOULD SAY THE OVERSHOOT TENDENCY IN THE RANDOM INPUT TRACKING TASKS WAS MILD. THE THING THAT BOTHERED ME MOST WAS THE ABRUPTNESS IN THE INITIAL RESPONSE RATHER THAN THE OSCILLATORY TENDENCY.	THE RANDOM DISTURBANCES AFFECTED THE AIRPLANE QUITE A BIT. WITH THE RANDOM DISTURBANCES PRESENT, THE STEADY-STATE AND MANEUVERING STICK FORCES SEEM HEAVIER. I DON'T KNOW WHETHER THIS IS TRUE OR NOT, BUT THAT'S THE WAY IT FEELS.	I LIKE THE RESPONSIVENESS AND THE DAMPING SEEMS GOOD.	THE SLIGHT TENDENCY TO OVERCONTROL OR OVERSHOOT, AND THE ABRUPTNESS IN THE INITIAL RESPONSE WERE OBJECTIONABLE.	I'M GOING TO GIVE IT A PIOR OF 2. I THINK THE AIRPLANE IS ON THE BORDERLINE BETWEEN SATISFACTORY AND UNSATISFACTORY BECAUSE OF A LOT OF LITTLE THINGS. THE STICK FORCES BEING A LITTLE HEAVY, THE ABRUPTNESS IN THE INITIAL RESPONSE, AND THE EFFECT THE RANDOM INPUTS HAD ON THE AIRPLANE ALL CONTRIBUTE TO MAKE ME FEEL THE AIRPLANE IS NOT QUITE AS GOOD AS IT SHOULD BE. I'LL RATE AN A-3.5.

B

TABLE IV-IV (Continued) PILOT COMMENT SUMMARY, PILOT B, FIXED $\frac{F_{EW}}{n_z}$

FLIGHT NO.	ω_{SP} $\frac{RAD}{SEC}$	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_z}$ LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
[illegible]	10.2	.[illegible]	4	1	GENERALLY I DON'T THINK THE AIRPLANE IS TOO BAD IN MOST RESPECTS. I THINK THE SHORT PERIOD IS WELL DAMPED. MY PRIMARY OBJECTION IS THE HIGH STICK FORCES. I HAD SOME DIFFICULTY TRIMMING. IT SEEMED AS THOUGH IT TOOK ME A LITTLE LONGER TO TRIM THAN I WOULD HAVE LIKED. AIRSPEED CONTROL WAS REASONABLE DURING TRIMMING. I HAD SOME SLIGHT DIFFICULTY WITH AIRSPEED CONTROL. I HAVE TO MANIPULATE THE THROTTLE A LOT TO MAINTAIN AIRSPEED SO I GET SOME TRIM CHANGE AND I BELIEVE THIS CAUSED THE DIFFICULTY IN ALTITUDE CONTROL. I HAD SOME PROBLEM WITH LONGITUDINAL CONTROL IN ENTRIES, MAINTAINING, AND RECOVERIES FROM TURNS. I HAD MORE DIFFICULTY WITH RATE OF CLIMB CONTROL. ONCE YOU GOT THE RATE OF CLIMB ESTABLISHED IT WASN'T TOO BAD.	THE STEADY STATE STICK FORCES SEEMED TO BE ON THE HEAVY SIDE. THE DISPLACEMENTS SEEMED TO BE MODERATE. IT SEEMED THAT I JUST HAD TO USE TOO MUCH FORCE TO OBTAIN A STEADY STATE G OF 1½ TO 2 INCREMENTAL.	47.0	THE INITIAL RESPONSE WASN'T REALLY TOO BAD. I WOULD PREFER TO HAVE THE INITIAL RESPONSE A LITTLE FASTER. THE FINAL RESPONSE IN THE STEADY STATE WASN'T REALLY TOO BAD, BUT IT SEEMED TO ME THAT I HAD TO WORK FAIRLY HARD TO HOLD THE G JUST BECAUSE OF THE HEAVY STICK FORCE.	I HAD SOME SLIGHT DIFFICULTY IN PITCH ATTITUDE CONTROL. FOR FINE PITCH ATTITUDE CONTROL WHEN MAKING SMALL INPUTS, THERE WAS A SLIGHT TENDENCY TO BOBBLE. MAINTAINING A STEADY STATE ACCELERATION DIDN'T SEEM TOO HARD. I MIGHT MENTION THAT CONTROL PRECISION SEEMED TO BE THE SAME IN BOTH POSITIVE AND NEGATIVE DIRECTIONS.	I THINK MY PERFORMANCE IN THE ST[illegible] TRACKING TASK WAS REASONABLY GOOD. IT SEEMED, HOWEVER, THAT I HAD QUITE A TENDENCY TO OVERCONTROL I[illegible] THE RANDOM INPUT TASK.
007	10.2	.67	3	1.5	THIS AIRPLANE IS NOT TOO BAD. I FELT THE STICK FORCES AND STICK MOTIONS WERE ON THE HIGH SIDE. I HAD NO OVERCONTROL TENDENCIES. I COULD PULL 2 G'S FAIRLY WELL ALTHOUGH THE STICK FORCES WERE A LITTLE HIGH. TRIMABILITY WAS OKAY. AIRSPEED CONTROL WAS OKAY. THE TRACKING CAPABILITY OF THIS AIRPLANE WAS QUITE GOOD. I COULD MAKE THE AIRPLANE TRACK FAIRLY WELL, FAIRLY RAPIDLY, WITH ONLY A VERY SLIGHT TENDENCY TO OVERSHOOT. ALTITUDE CONTROL WAS GOOD. LONGITUDINAL CONTROL IN TURNS WAS QUITE GOOD. I DID HAVE A LITTLE TROUBLE ESTABLISHING AN EXACT RATE OF CLIMB OR DESCENT IN THE TURNS BUT I THINK THAT IS PARTLY DUE TO THE SENSITIVITY OF THE AIRPLANE AT HIGH SPEEDS.	THE STICK FORCES SEEMED TO BE A BIT ON THE HEAVY SIDE IN THE STEADY STATE AND ALSO FELT A LITTLE STIFF FOR THE SMALL AMPLITUDE INPUTS. STICK DISPLACEMENTS SEEMED TO BE A LITTLE LARGE.	45.0	INITIAL RESPONSE WAS QUITE GOOD. IT COULD HAVE BEEN MAYBE JUST A LITTLE BETTER. IT DIDN'T FEEL VERY ABRUPT AND I DIDN'T HAVE ANY TENDENCY TO OVERSHOOT TO SPEAK OF. I DID FEEL THAT THE STICK FORCES WERE A LITTLE HEAVY BUT IF THEY WERE LIGHTER I MAY NOT HAVE LIKED THE INITIAL RESPONSE. THE FINAL RESPONSE WAS A BIT ON THE HEAVY SIDE. FOR THIS TYPE OF AIRCRAFT, HOWEVER, IT MAY NOT BE TOO BAD, BUT I WOULD CERTAINLY PREFER LIGHTER FORCES.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WAS QUITE GOOD.	THE AIRPLANE'S PERFORMANCE IN THE [illegible] ATTITUDE TRACKING TASK WAS GOOD [illegible]CEPT THAT OCCASIONALLY IT TOOK [illegible] A BIT OF FORCE TO MAKE AN ATTITU[illegible] CHANGE. I COULD MAKE RATHER LA[illegible] INPUTS WITHOUT OVERSHOOTING. MY PERFORMANCE IN THE RANDOM INPUT TRACKING TASK WAS ALSO QUITE GOOD.

A

ARY, PILOT B, FIXED $\frac{F_{EW}}{n_z}$ GROUP II ($1/T_{\theta_2} \approx 2.65$, $n_z/\alpha \approx 56.2$ g/RAD, $\zeta_{sp} \approx 0.7$, $V_T = 685$ FT/SEC)

H ATTITUDE D NORMAL ATION CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
DIFFICULTY IN PITCH FOR FINE PITCH ATTI- MAKING SMALL INPUTS. T TENDENCY TO BOBBLE ADY STATE ACCELERATION ARD. I MIGHT MENTION ISION SEEMED TO BE POSITIVE AND NEGATIVE	I THINK MY PERFORMANCE IN THE STEP TRACKING TASK WAS REASONABLY GOOD IT SEEMED, HOWEVER, THAT I HAD QUITE A TENDENCY TO OVERCONTROL IN THE RANDOM INPUT TASK.	THE AIRPLANE IS CERTAINLY VERY RESPONSIVE TO RANDOM INPUTS. YOU HAVE A HIGH FRE-QUENCY TYPE RESPONSE AND I BELIEVE YOU'D HAVE TROUBLE TRYING TO REFUEL WITH THIS AIRPLANE IN TURBULENCE. YOU'RE JUST NOT ABLE TO MAINTAIN REAL TIGHT CONTROL WITH THESE RANDOM INPUTS.	THE AIRPLANE HAD GOOD DAMPING IN PITCH.	THE PRIMARY OBJECTIONABLE FEATURE IS THE HIGH STICK FORCE GRADIENT.	THERE'S NOT MUCH PIO TENDENCY EXCEPT FOR SMALL INPUTS AROUND THE TRIM POINT AND WHEN YOU'RE FLYING VERY TIGHTLY IN THE TRACKING TASK. THE AIRCRAFT IS CONTROLLABLE AND ACCEPTABLE, BUT I THINK IT IS UNSATISFACTORY. I THINK WE SHOULD IMPROVE THE STICK FORCES. I'M GOING TO RATE AN A-4.
NORMAL ACCELERATION GOOD.	THE AIRPLANE'S PERFORMANCE IN THE ATTITUDE TRACKING TASK WAS GOOD EX-CEPT THAT OCCASIONALLY IT TOOK QUITE A BIT OF FORCE TO MAKE AN ATTITUDE CHANGE. I COULD MAKE RATHER LARGE INPUTS WITHOUT OVERSHOOTING. MY PERFORMANCE IN THE RANDOM INPUT TRACKING TASK WAS ALSO QUITE GOOD.	THE AIRPLANE IS MORE RESPONSIVE TO RANDOM DISTURBANCES THAN I WOULD LIKE. THE AIRPLANE AGAIN FELT HEAVIER IN A TURN WITH THE RANDOM DISTURBANCES THAN WITHOUT. THE RIDE WAS UNCOMFORTABLE.	THE INITIAL RESPONSE IS GOOD. THERE'S NO TENDENCY TO OVER-SHOOT OR OSCILLATE. THE DAMP-ING WAS GOOD.	THE STICK FORCES WERE SOMEWHAT HIGH AND THE STICK MOTIONS WERE A LITTLE ON THE LARGE SIDE.	THERE'S A VERY, VERY SLIGHT TENDENCY TOWARDS PIO SO I'LL CALL IT A 1½. SOME SLIGHT IMPROVEMENT COULD BE MADE IN THE AIRPLANE'S STICK FORCES AND STICK MOTIONS SO YOU COULD GET MORE PRECISION WITH LESS PILOT EFFORT. I'LL CALL THIS AN A-3.

B

TABLE IV-V PILOT COMMENT SUMMARY, PILOT A, $\frac{F_{EW}}{n_g}$ SELECTED BY PI

FLIGHT NO.	ω_{SP} $\frac{RAD}{SEC}$	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_g}$ LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
003	2.06	.71	6	1	THE AIRPLANE IS FAIRLY SOLID IN TERMS OF NOT WANDERING AROUND THE SKY BUT IT'S A LITTLE BIT SLUGGISH IN MANEUVERING.	IN PICKING THE STICK FORCE PER G, I FOUND IT WAS A REAL COMPROMISE BETWEEN TRYING TO IMPROVE MY SPEED OF TRACKING OR PITCH RATE CAPABILITY BY REDUCING THE STICK FORCE WITHOUT COMPROMISING THE STEADY STATE STICK FORCE PER G AS FAR AS STRUCTURAL PROTECTION IS CONCERNED. I BASICALLY PICKED A STICK FORCE PER G THAT GAVE THE AIRPLANE STRUCTURAL PROTECTION AND COMPROMISED MY TRACKING ABILITY SOMEWHAT. I WOULD HAVE LIKED LIGHTER FORCES FOR BETTER TRACKING CAPABILITY.	61.2	THE INITIAL RESPONSE OF THE AIRPLANE TENDS TO BE SOMEWHAT SLUGGISH. YOU END UP SORT OF PULLING AND RELEASING THE FORCE IN ORDER TO GET THE AIRPLANE TO WHERE YOU WANT. IF YOU PULL TOO HARD, IT'S DIFFICULT TO ACHIEVE A SMOOTH FINAL RESPONSE WITHOUT A TENDENCY TO BOBBLE BEFORE IT SETTLES DOWN.	FOR SMALL CORRECTIONS, ONCE YOU'VE PULLED TO WHERE YOU WANT TO GO, THE PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL IS OKAY. THERE IS A TENDENCY TO OVERCONTROL IN G UNLESS I RELEASE THE STICK FORCE OR I MAKE A LARGE ATTITUDE CHANGE. IF YOU DO THINGS SLOWLY SO THAT YOU ARE NOT REALLY USING THE SHORT PERIOD DYNAMICS, I DON'T SEE ANYTHING DETRIMENTAL.	ON THE STEP ATTITUDE TRACKI SORT OF ACCEPT THE PITCH RA HAVE TO ANTICIPATE WHERE YO AND RELEASE YOUR INPUT. OR WHERE I HAVE TO ACT AS A CO PORTIONAL CONTROLLER, I CAN' GOOD JOB. IF I STAY IN THE CONTINUOUSLY I TEND TO OSCIL I'M NOT GETTING THE INITIAL THINK I WANT AT TIMES. I EN PULSING THE CONTROL AND WAIT WHERE IT WAS GOING AND PULSE
004	4.29	.66	3	1.5	THE AIRPLANE IS REALLY QUITE NICE. IT IS FAIRLY RESPONSIVE AND THE DAMPING IS GOOD. TRACKING FEELS PRETTY GOOD ALL AROUND.	THERE ARE NO PROBLEMS WITH STICK DISPLACEMENTS. THE STICK FORCES I PICKED WERE DETERMINED BASICALLY FOR STRUCTURAL PROTECTION IN STEADY G SYMMETRICAL PULL-UPS. ALTHOUGH NOT OVERLY HIGH, THE FORCES TO HOLD A STEADY G IN A TURN ARE A LITTLE BIT HIGH. IF I LIGHTEN UP ON THE FORCES THERE IS A TENDENCY TO OVERDRIVE THE G ON A PULL-OUT, BUT IT'S THE ONLY TIME I NOTICE IT, SO THAT WAS THE DETERMINING FACTOR IN MY SELECTION. EXCEPT FOR THE STEADY STATE STICK FORCE IN A TURN, IT FEELS FAIRLY GOOD.	10.9	THE INITIAL RESPONSE IS QUITE GOOD, QUITE QUICK BUT NOT OVERLY SENSITIVE. IT JUST FEELS GOOD. THE FINAL RESPONSE BEHAVES QUITE NICELY.	I HAD GOOD CONTROL OF ATTITUDE AND G. YOU COULD BE VERY PRECISE IN YOUR ABILITY TO PUT THE NOSE WHERE YOU WOULD LIKE. I THOUGHT MY ABILITY TO PULL AND HOLD G WAS VERY GOOD.	THE TRACKING I THINK IS REALL PRECISE. YOU CAN MAKE IT ST YOU WANT IT. UNLESS YOU REAL UP YOUR CONTROL, THERE IS NO BOBBLE. I DID NOTICE FOR REA TUDE CONTROL, I COULD INDUCE BOBBLE TENDENCY.
[illegible]	5.52	.87	3	1.5	IT'S A NICE AIRPLANE. IT'S PRECISE IN TERMS OF CONTROLLABILITY FOR THE TYPE MISSION YOU WOULD EXPECT TO PERFORM. I DID NOTICE THAT IF YOU TEND TO BE VERY ABRUPT WITH THE AIRPLANE, YOU START TO GET A SLIGHT OSCILLATION CREEPING INTO THE RESPONSE. I DON'T THINK THAT YOU WOULD BE FLYING THE AIRPLANE AS TIGHT AS I WAS WHEN THESE BOBBLES SHOWED UP. SO, OVERALL THE AIRPLANE FEELS GOOD. NO PROBLEM GETTING TO A NEW ALTITUDE AND HOLDING IT. NO PROBLEMS WITH LONGITUDINAL CONTROL IN TURNS AS LONG AS THE INPUTS WEREN'T REALLY ABRUPT. CLIMBING AND DESCENDING TURNS SHOWED NO PROBLEMS.	THE STICK FORCE I SELECTED WAS PRIMARILY DETERMINED BY WHAT I THOUGHT WAS NECESSARY TO GIVE ME STRUCTURAL PROTECTION IN SYMMETRICAL PULL-OUTS. THIS VALUE WAS REALLY NOT TOO DIFFERENT FROM WHAT I WOULD HAVE PICKED FOR THE STEADY G TURN. THE FORCE I PICKED WAS REASONABLE FOR A 3 G AIRPLANE. I DID NOT GET THE FEELING THAT I WAS GETTING ANY APPRECIABLE STICK DISPLACEMENTS.	55.2	THE INITIAL RESPONSE IS MEDIUM QUICK. IT IS NICE FOR THIS TYPE MISSION. THE FINAL RESPONSE DOES HAVE SOME SLIGHT BOBBLE TENDENCY. HOWEVER, FOR THIS MISSION, WHERE THERE WOULD BE NO VERY WILD MANEUVERING, I THINK THE RESPONSE IS OKAY.	FOR SLOWER MANEUVERING, IF YOU'RE EASING INTO A TARGET AND DON'T HAVE TO MAKE ANY FAST CORRECTIONS, YOU FEEL FAIRLY PRECISE. IF YOU DO TEND TO DO THINGS A LITTLE FASTER THEN YOU WILL SEE A TENDENCY TO OVERSHOOT A LITTLE. I DON'T THINK THAT ANY OF THE INPUTS THAT I WOULD BE PUTTING IN DURING A NORMAL MISSION WOULD BE SUCH THAT THE SLIGHT BOBBLE TENDENCY WOULD SHOW UP.	I DIDN'T NOTICE ANY OUTSTANDI IN THE TRACKING TASKS. AGAIN, YOURSELF TO REALLY DRIVE THE A HARD, THEN YOU CAN SEE A SLIGH TO BOBBLE.
[illegible]	7.06	.87	5	3	THE AIRPLANE IS NOT TOO BAD AS LONG AS YOU CAN MANEUVER SLOWLY, MAKE NO LAST MINUTE QUICK CORRECTIONS, AND FLY IN SMOOTH AIR. YOUR PERFORMANCE DETERIORATES VERY RAPIDLY WHEN MAKING SMALL ABRUPT INPUTS OR WHEN FLYING IN TURBULENCE. THERE WAS NO GREAT PROBLEM WITH TRIMMING. YOU DO TEND TO GET A LITTLE BOBBLE FROM THE AIRPLANE WHEN MAKING FAST TRIM CHANGES. THERE WAS NO PROBLEM DEFINING THE TRIM CONDITION. AIRSPEED CONTROL WAS FAIRLY GOOD. ABILITY TO ACQUIRE AND STABILIZE ON A NEW ALTITUDE WAS GOOD. NO PROBLEM WITH LONGITUDINAL CONTROL IN TURNS. THERE IS A SPECIAL PILOTING TECHNIQUE IN THAT YOU HAVE TO ACCEPT LESS RAPID CONTROL INPUTS THAN YOU WOULD LIKE. YOU HAVE TO EASE INTO THINGS AND HOPE YOU GET WHAT YOU WANT.	THE STICK FORCE I SETTLED ON WAS DETERMINED BASICALLY BY OVERSTRESS CONSIDERATIONS IN A SYMMETRICAL PULL-OUT. I FELT THIS LEVEL OF FORCE WAS NEEDED TO KEEP ME FROM OVER-G-ING THE AIRPLANE. I DIDN'T NOTICE ANY STICK DISPLACEMENTS. I FELT AS THOUGH I WAS FLYING MOSTLY BY FORCE.	56.0	THE INITIAL RESPONSE IS VERY NICE. IT IS SMOOTH AND PRECISE I THINK. IT IS NOT SLUGGISH AND IT IS NOT OVERLY RESPONSIVE. THE FINAL RESPONSE IS WHERE THE DIFFICULTY STARTS. IF YOU MAKE A SUDDEN, SHARP INPUT YOU TEND TO GET ONE OR TWO BOBBLES BEFORE YOU SETTLE DOWN ON THE TARGET. IF YOU CAN ROLL RIGHT ONTO A TARGET WITHOUT MAKING ANY LAST MINUTE CORRECTIONS YOU WON'T SEE THIS BOBBLE. HOWEVER, FOR SMALL PITCH CORRECTIONS OR TO CHANGE TARGETS AND ACQUIRE A NEW ONE, YOU DEFINITELY WILL SEE THESE BOBBLES.	PITCH ATTITUDE CONTROL WAS GOOD AS LONG AS YOU MANEUVER SLOWLY AND SMOOTHLY. YOU DO, HOWEVER, HAVE A BOBBLING TENDENCY IF YOU TRY TO BE ABRUPT. NORMAL ACCELERATION CONTROL IS FAIRLY GOOD SINCE YOU DON'T NORMALLY HAVE TO MAKE A LOT OF SMALL CORRECTIONS.	IF YOU WANT TO DO THE TRACKING ANY DEGREE OF RAPIDITY, YOU JU CAN'T GET AWAY FROM THIS BOBBL TENDENCY. ON THE STEP INPUTS MYSELF OVERSHOOTING ONCE OR TW BEFORE SETTLING ON THE NEW ATT ON THE RANDOM INPUT TRACKING, IT ALMOST IMPOSSIBLE TO STAY WI TRACKING NEEDLE SINCE I WAS BOB AROUND CONSTANTLY.
[illegible]	7.06	.66	4	2	THE AIRPLANE IS NOT TOO UNREASONABLE. IT HAS A GOOD RESPONSE BUT THERE IS A SLIGHT TENDENCY TO BOBBLE IN PITCH WITH TIGHT CONTROL.	THE STICK FORCES WERE DETERMINED BY WHAT I FELT WAS NEEDED FOR STRUCTURAL PROTECTION IN A SYMMETRICAL PULL-OUT. CONSEQUENTLY THE STICK FORCES ARE A LITTLE HIGH IN THE STEADY STATE BUT THEY ARE ACCEPTABLE. THE STICK DISPLACEMENTS WERE NOT NOTICEABLE.	52.3	THE INITIAL RESPONSE TO THE PILOT'S INPUT IS A NICE FEELING, YOU GET THE PITCH RATE YOU'D LIKE TO SEE. IN THE FINAL RESPONSE YOU TEND TO GET A COUPLE OF OVERSHOOTS BEFORE IT SETTLES DOWN IF YOU ARE MAINTAINING TIGHT CONTROL.	THE INITIAL PITCH ACCELERATION AND PITCH RATE SEEM NATURAL, GOOD. THE RESPONSE IS NOT SO ABRUPT THAT IT STARTLES YOU AND IT'S NOT SO SLUGGISH THAT YOU ARE HAVING TO PULL WITH A NOTICEABLE FORCE BEFORE THE NOSE MOVES. NORMAL ACCELERATION CONTROL IN TERMS OF HOLDING A STEADY G IS NO PROBLEM.	WHEN I FLEW THE TRACKING TASKS W A LOWER GAIN I HAD NO PROBLEMS. HOWEVER, WHEN I TIGHTENED UP ON CONTROL GAIN I HAD A BOBBLING TE DENCY.

A

$\frac{F_{EW}}{n_g}$ SELECTED BY PILOT GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_z/\alpha \approx 16.5$ g/RAD, $\zeta_{sp} \approx 0.7$, $V_T = 411$ FT/SEC)

...TUDE ...L CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
..., ONCE YOU'VE ...T TO GO, THE ...AL ACCELERATION ... IS A TENDENCY TO ...S I RELEASE THE A LARGE ATTITUDE ...S SLOWLY SO THAT ...G THE SHORT ...'T SEE ANYTHING	ON THE STEP ATTITUDE TRACKING TASK, YOU SORT OF ACCEPT THE PITCH RATE YOU GET AND HAVE TO ANTICIPATE WHERE YOU WANT TO STOP AND RELEASE YOUR INPUT. ON THE OTHER TASK WHERE I HAVE TO ACT AS A CONTINUOUS PROPORTIONAL CONTROLLER, I CAN'T DO A VERY GOOD JOB. IF I STAY IN THE CONTROL LOOP CONTINUOUSLY I TEND TO OSCILLATE BECAUSE I'M NOT GETTING THE INITIAL RESPONSE I THINK I WANT AT TIMES. I ENDED UP SORT OF PULSING THE CONTROL AND WAITING TO SEE WHERE IT WAS GOING AND PULSED IT TO STOP.	I DIDN'T REALLY SEE A WHOLE LOT OF DISTURBANCE IN THE AIRPLANE AS A RESULT OF THE RANDOM DISTURBANCE. IT HARDLY AFFECTED MY CONTROL.	IT'S GOOD IN THE SENSE THAT THE AIRPLANE IS NOT OSCILLATORY AND ONCE YOU GET IT WHERE YOU WANT, IT IS SOLID AND NICE.	IN GETTING WHERE YOU WANT IT TO GO, THE AIRPLANE IS A LITTLE MORE SLUGGISH THAN I WOULD LIKE. I REALLY HAD TO COMPROMISE MY TRACKING ABILITY BY MAKING THE STICK FORCES HEAVIER THAN I WOULD LIKE TO GIVE STRUCTURAL PROTECTION. IF YOU START TO EASE INTO A HIGHER MANEUVER YOU TEND TO OVERSHOOT WHAT YOU INITIALLY THINK YOU'LL GOING TO GET.	THERE'S NO PIO TENDENCY. WITH THE RELATED STICK FORCE PER G I CERTAINLY DON'T FEEL THE AIRPLANE IS SATISFACTORY, HOWEVER, YOU CAN COMPENSATE FOR THE LACK OF RESPONSE BY PULLING HARD AND RELEASING YOUR INPUT AS YOU APPROACH THE DESIRED ATTITUDE.
...TTITUDE AND G. ...E IN YOUR ... WHERE YOU WOULD ...LITY TO PULL AND	THE TRACKING I THINK IS REALLY NICE, REAL PRECISE. YOU CAN MAKE IT STOP RIGHT WHERE YOU WANT IT. UNLESS YOU REALLY TIGHTEN UP YOUR CONTROL, THERE IS NO TENDENCY TO BOBBLE. I DID NOTICE FOR REAL TIGHT ATTITUDE CONTROL, I COULD INDUCE A LITTLE BOBBLE TENDENCY.	I FELT THE MAGNITUDE OF THE RANDOM INPUT WAS NOT OVERLY HIGH AND I DIDN'T SEE ANY PROBLEM IN TRYING TO STAY WITH THE AIRPLANE AND PERFORMING THE TASKS.	THE AIRPLANE IS VERY RESPONSIVE. YOU SORT OF THINK WHAT YOU WANT AND IT HAPPENS. THE DAMPING IS GOOD AND FOR MOST MANEUVERING THERE IS NO TENDENCY TO BOBBLE AND THE TRACKING IS PRETTY GOOD.	EXCEPT FOR THE SLIGHT TENDENCY TO BOBBLE SOMEWHAT WHEN YOU'RE REALLY TRYING TO PIN DOWN A TARGET WHICH IS SOMEWHAT OUTSIDE OF THE SCOPE OF THE AIRPLANE, I CAN'T SEE ANY REAL OBJECTIONABLE FEATURES.	THIS ONE IS CERTAINLY SATISFACTORY FOR THE MISSION. I REALLY WOULDN'T ASK THAT ANYTHING BE FIXED. HOWEVER, BECAUSE THIS SLIGHT TENDENCY TO BOBBLE THE AIRPLANE IS PRESENT, IT'S ENOUGH TO DROP THE RATING TO A LOW SATISFACTORY.
... IF YOU'RE EASING ...T HAVE TO MAKE ANY ...FEEL FAIRLY PRECISE. ...HINGS A LITTLE FASTER ...DENCY TO OVER- ...T THINK THAT ANY ...ULD BE PUTTING IN ... WOULD BE SUCH THAT ...ENCY WOULD SHOW UP.	I DIDN'T NOTICE ANY OUTSTANDING PROBLEMS IN THE TRACKING TASKS. AGAIN, IF YOU FORCE YOURSELF TO REALLY DRIVE THE AIRPLANE HARD, THEN YOU CAN SEE A SLIGHT TENDENCY TO BOBBLE.	I DIDN'T FEEL THAT THE RANDOM DISTURBANCES WERE HINDERING MY PERFORMANCE TO ANY GREAT EXTENT. I DIDN'T FEEL THAT THE DYNAMICS OF THE AIRPLANE WERE CAUSING ANY EXAGGERATION IN THE DEGRADATION OF CONTROL DUE TO THE RANDOM INPUTS.	GOOD FEATURES INCLUDE THE PRECISE RESPONSE AND THE GOOD, TIGHT CONTROL YOU HAVE WHEN TRYING TO MANEUVER OR INITIATE A MANEUVER. THE STICK FORCE AND AIRPLANE RESPONSE SEEM TO GO WELL TOGETHER.	THE ONLY OBJECTIONABLE FEATURE WOULD BE THE SLIGHT TENDENCY TO BOBBLE WHEN YOU'RE MAINTAINING EXTREMELY TIGHT CONTROL.	IT'S NOT A PIO RATING OF I BECAUSE OF THIS SLIGHT TENDENCY TO BOBBLE WHEN YOU'RE MAKING ABRUPT MANEUVERS. I'LL RATE IT A 1½. I WOULD RATE IT AT THE BOTTOM END OF THE SATISFACTORY REGION REALIZING THAT IF YOU TRY TO DRIVE THE AIRPLANE A LITTLE BIT HARDER IN THE MISSION THEN YOU WILL SEE THIS BOBBLE. I'LL RATE IT AN A-3.
... WAS GOOD AS LONG ... AND SMOOTHLY. ...A BOBBLING TENDENCY ...T. NORMAL ACCELERATION ... SINCE YOU DON'T ...A LOT OF SMALL	IF YOU WANT TO DO THE TRACKING WITH ANY DEGREE OF RAPIDITY, YOU JUST CAN'T GET AWAY FROM THIS BOBBLING TENDENCY. ON THE STEP INPUTS I FOUND MYSELF OVERSHOOTING ONCE OR TWICE BEFORE SETTLING ON THE NEW ATTITUDE. ON THE RANDOM INPUT TRACKING, I FOUND IT ALMOST IMPOSSIBLE TO STAY WITH THE TRACKING NEEDLE SINCE I WAS BOBBLING AROUND CONSTANTLY.	MY IMPRESSION AFTER FLYING THIS AIRPLANE IN THE PRESENCE OF RANDOM DISTURBANCES IS THAT THE AIRPLANE WOULD BE VERY DIFFICULT TO CONTROL IN TURBULENCE. YOU WOULDN'T BE ABLE TO MAKE SMALL CORRECTIONS. I THINK YOU'D JUST HAVE TO EASE INTO THINGS SLOWLY AND HOPE YOU COULD STAY ON THE TARGET LONG ENOUGH TO TRACK BEFORE THE TURBULENCE BOUNCED YOU OFF.	THE AIRPLANE IS INITIALLY QUITE RESPONSIVE. YOU CAN MAINTAIN AN ATTITUDE VERY NICELY AS LONG AS THERE ARE NO DISTURBANCES.	THE BOBBLING TENDENCY FOR SMALL INPUTS AND THE CONTROL IN TURBULENCE ARE OBJECTIONABLE FEATURES.	PIO'S ARE USUALLY INDUCED WHEN YOU INITIATE AN ABRUPT MANEUVER OR ATTEMPT TIGHT CONTROL. IT DOESN'T TAKE CONSIDERABLE PILOT ATTENTION BUT YOU MAY HAVE TO SACRIFICE PERFORMANCE BECAUSE YOU MAY NOT BE ABLE TO STOP THE NOSE WHERE YOU WANT IT. I WOULD RATE IT A 3. THE AIRPLANE IS IN THE UNSATISFACTORY REGION BECAUSE OF THESE OSCILLATORY MOTIONS. I FEEL YOU COULD DO THE MISSION WITH THE AIRCRAFT. I'M GOING TO DOWNGRADE THIS CONFIGURATION MAINLY DUE TO THE PERFORMANCE YOU COULD EXPECT IN TURBULENCE. I FEEL IT WOULD BE VERY DIFFICULT TO TRACK PREC SELY. I'LL RATE IT AN A-6.
...ERATION AND PITCH ... THE RESPONSE IS ...TARTLES YOU AND ...AT YOU ARE HAVING TO ...FORCE BEFORE THE ...LERATION CONTROL ...TEADY G IS NO PROBLEM.	WHEN I FLEW THE TRACKING TASKS WITH A LOWER GAIN I HAD NO PROBLEMS. HOWEVER, WHEN I TIGHTENED UP ON MY CONTROL GAIN I HAD A BOBBLING TENDENCY.	I DIDN'T FEEL THAT THERE WAS ANY DETERIORATION OF MY PERFORMANCE DUE TO ANY INTERACTION BETWEEN THE AIRPLANE DYNAMICS AND THE RANDOM NOISE.	THE AIRPLANE FEELS VERY RESPONSIVE. ONCE YOU'RE STABILIZED ON TARGET, THE AIRPLANE IS SOLID.	IF YOU TRY TO CLOSE THE LOOP TOO TIGHTLY, YOU GET A SMALL BOBBLE ESPECIALLY WHEN YOU'RE TRYING TO PIN DOWN A TARGET.	THIS IS A SOLID PIOR OF 2. UNDESIRABLE MOTIONS DO TEND TO OCCUR WHEN THE PILOT INITIATES ABRUPT CONTROL BUT THEY CAN BE ELIMINATED BY PILOT TECHNIQUE. THE DEFICIENCIES I SEE ARE MINOR AND I'D LIKE TO SEE THEM CHANGED, BUT I CAN DO THE MISSION. I'D LIKE TO SEE THE BOBBLES IN THE FINAL RESPONSE FIXED. I'LL RATE IT AN A-4.

B

TABLE IV-VI PILOT COMMENT SUMMARY, PILOT B, $\frac{F_{EW}}{n_g}$ SELECTED BY PILOT GR

FLIGHT NO.	ω_{SP} RAD/SEC	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_g}$ lb/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
900	2.12	.80	4.5	2	THIS IS A SLUGGISH AIRPLANE. THE AIRPLANE FEELS TOO SOFT. THE INITIAL RESPONSE IS NOT GOOD ENOUGH SO THAT THE PILOT HAD TO OVERDRIVE THE AIRPLANE. TRIMABILITY WAS FAIR. WITH THE STICK FORCE I CHOSE, THIS IS ONLY A FAIR AIRCRAFT.	THE STICK FORCES WERE CHOSEN WITH STRUCTURAL PROTECTION AS THE MAJOR CONSIDERATION. IF I PICKED FORCES LIGHT ENOUGH FOR MY LIKING, THEN I HAD A TENDENCY TO OVERCONTROL OR OVERDRIVE THE AIRPLANE. THE STICK MOTIONS FEEL A LITTLE BIT LARGE.	56.9	INITIAL RESPONSE IS TOO SLUGGISH. I HAVE TO MAKE LARGE INPUTS INITIALLY TO GET THINGS GOING, THEN ANTICIPATE THE FINAL ATTITUDE I WANT AND PUT IN AN INPUT IN THE OPPOSITE DIRECTION. THE FINAL RESPONSE SEEMS OKAY, BUT IT DOES SEEM THAT TO MAKE ANY CORRECTION I HAVE TO MOVE THE STICK A GREAT DEAL.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL IS ONLY FAIR. THERE'S A DEFINITE TENDENCY TO OVERSHOOT ALTHOUGH THE OVERSHOOTS AREN'T VERY LARGE.	FOR THE STEP TRACKING TASK, IT TOO LONG TIME TO ZERO THE ERROR SIGNAL THE DISPLAY. YOU HAD TO MAKE LARGE PUTS THEN TAKE IT OUT AND SEE WHE WERE GOING TO END UP. FOR THE RAN INPUT TASK IT SEEMED LIKE EVERYTHI WAS HAPPENING IN SLOW MOTION. YOU TO ANTICIPATE CONTROL INPUTS MUCH THAN NORMAL.
902	4.2	.67	3	2	IN GENERAL, I THOUGHT THIS WAS A PRETTY GOOD AIRPLANE. HOWEVER, I HAD THE IMPRESSION THAT I HAD TO PUSH THE AIRPLANE A LITTLE.	I THINK I MAY HAVE MADE A SLIGHT ERROR IN PICKING THE STICK FORCES. THEY MAY HAVE BEEN A BIT ON THE HEAVY SIDE. I HAD TO MAKE A COMPROMISE TO REDUCE THE TENDENCY TO OVERCONTROL IN THE TRACKING TASKS. I HAD A TENDENCY TO OVERSHOOT THE DESIRED ATTITUDE SIGNIFICANTLY SO I CHOSE THE HEAVIER FORCE. THE STICK DISPLACEMENTS SEEMED SOMEWHAT ON THE LARGE SIDE. MAYBE THIS WAS BECAUSE I WAS PUSHING OR OVERDRIVING THE AIRPLANE.	53.6	THE INITIAL RESPONSE WAS PRETTY GOOD FOR THIS CLASS OF AIRPLANE. IT CERTAINLY WASN'T ABRUPT. THE FINAL RESPONSE WAS OKAY, ALTHOUGH I HAD THE FEELING THAT IF I WANTED TO PULL 2 1/2 INCREMENTAL g'S IT MIGHT FEEL SOMEWHAT ON THE HEAVY SIDE.	PITCH ATTITUDE, NORMAL ACCELERATION CONTROL AND TRACKING CAPABILITY WERE PRETTY GOOD. I HAD THE FEELING THAT I DIDN'T HAVE REAL TIGHT CONTROL OF IT, BUT IT WASN'T TOO BAD.	I HAD A VERY SLIGHT TENDENCY TO OV SHOOT IN THE STEP TRACKING TASK. THE RANDOM INPUT TASK I HAD A LITT TROUBLE KEEPING UP WITH THE CHANGE THE SIGNAL AND FELT I WAS ALWAYS A LITTLE BEHIND. I FOUND MYSELF THE AIRCRAFT A LITTLE BIT AROUND T TRIM POINT. IF I ADJUSTED MY GAIN COULD REDUCE THE BOBBLING TENDENCY THE OVERALL TRACKING ACCURACY WOU DOWN.
902	5.77	.65	2	1.5	I THOUGHT THIS AIRPLANE WAS QUITE GOOD. I HAVEN'T SEEN ANY CHARACTERISTICS WHICH WOULD GIVE ME ANY GREAT DIFFICULTY. THERE WAS SOME SLIGHT TENDENCY TO OVERCONTROL FOR SMALL AMPLITUDE INPUTS.	I THINK NORMALLY I WOULD LIKE SLIGHTLY LIGHTER STICK FORCES THAN I PICKED FOR THIS CONFIGURATION. HOWEVER, THE FORCES I CHOSE DO REDUCE THE TENDENCY TO OVERCONTROL IN THE TIGHT TRACKING TASKS. THE STEADY STATE FORCES SEEM A LITTLE ON THE HEAVY SIDE. STICK DISPLACEMENTS ARE MODERATE.	52.8	THE INITIAL RESPONSE WAS QUITE GOOD. THE FINAL RESPONSE SEEMED REASONABLE. I CAN REACH A STEADY STATE VERY EASILY AND THEN MAKE SMALL CORRECTIONS ABOUT THE STEADY STATE WITH NO TROUBLE.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL I THINK, ARE QUITE GOOD.	THERE WAS A SLIGHT TENDENCY TO OVE CONTROL IN THE STEP TRACKING TASK, DOES SEEM THOUGH THAT I CAN GET F ONE POINT TO ANOTHER VERY RAPIDLY WITH JUST A MINOR CORRECTION ZERO THE PITCH ATTITUDE ERROR. THE TEN CY TO OVERCONTROL WAS A LITTLE MOR NOTICEABLE IN THE RANDOM INPUT TAS
901	7.25	.66	3	2	THIS IS A PRETTY FAIR AIRPLANE. IT MIGHT BE JUST A LITTLE TOO SNAPPY FOR SMALL INPUTS. IN A VERY TIGHT TRACKING TASK THERE IS A TENDENCY TO BOBBLE THE AIRPLANE A LITTLE. THE AIRPLANE IS VERY RESPONSIVE, ALMOST FIGHTER LIKE.	I GET THE FEELING FOR SMALL INPUTS AROUND THE TRIM POINT, THAT THE STICK FORCES ARE MAYBE A LITTLE BIT ON THE LIGHT SIDE; HOWEVER, THE STEADY STATE FORCES SEEM ABOUT RIGHT. THE STICK DISPLACEMENTS SEEM REASONABLE. I'D SAY THEY'RE MODERATE.	43.0	THE INITIAL RESPONSE IS FAIRLY FAST AND IT'S APPROACHING BEING ABRUPT. THERE IS A TENDENCY TO OVERSHOOT THE DESIRED ATTITUDE AND BOBBLE SLIGHTLY. THE AIRPLANE IS WELL DAMPED SO YOU MAY OVERSHOOT SLIGHTLY BUT YOU JUST RELAX AND YOU'RE RIGHT BACK ON THE DESIRED ATTITUDE. IT JUST TAKES A LITTLE LONGER THAN NORMAL. THE FINAL RESPONSE TO PILOT INPUTS WAS QUITE GOOD.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WAS FAIRLY GOOD EXCEPT FOR THE TENDENCY TO BOBBLE SLIGHTLY.	ON THE STEP ATTITUDE TRACKING, I W OVERSHOOT A LITTLE WHILE CANCELLI THE ERROR SIGNAL. THE INITIAL RESP SEEMED TO BE A LITTLE ABRUPT FOR A LARGER STEP. I HAD A TENDENCY TO OV DRIVE THE AIRPLANE A LITTLE. IN THE RANDOM INPUT TRACKING TASK I THINK TENDENCY TO BOBBLE WAS EVEN MORE NOTICEABLE.

A

$\frac{F_{EW}}{n_g}$ SELECTED BY PILOT GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_z/\alpha \approx 16.5$ g/RAD, $\zeta_{sp} \approx 0.7$, V_T = 411 FT/SEC)

...D ATTITUDE ...D NORMAL ...RATION CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
...D NORMAL ACCELERATION CONTROL ...HERE'S A DEFINITE TENDENCY TO ...ON THE OVERSHOOTS AREN'T	FOR THE STEP TRACKING TASK, IT TOOK A LONG TIME TO ZERO THE ERROR SIGNAL ON THE DISPLAY. YOU HAD TO MAKE LARGE INPUTS THEN TAKE IT OUT AND SEE WHERE YOU WERE GOING TO END UP. FOR THE RANDOM INPUT TASK IT SEEMED LIKE EVERYTHING WAS HAPPENING IN SLOW MOTION. YOU HAVE TO ANTICIPATE CONTROL INPUTS MUCH MORE THAN NORMAL.	THE AIRPLANE DID NOT RESPOND MUCH TO THE RANDOM DISTURBANCES. MY CONTROL WAS NOT AFFECTED.	THE GOOD DAMPING IN PITCH WITH THE HEAVY STICK FORCE I PICKED. THERE WASN'T MUCH OVERSHOOT TENDENCY.	YOU DON'T HAVE VERY TIGHT CONTROL OF THE ATTITUDE. THE RESPONSE IS SLUGGISH.	THERE WAS A MILD TENDENCY TOWARDS PIO. THERE WAS A TENDENCY TO OVERSHOOT, BUT THIS COULD BE ELIMINATED BY PILOT TECHNIQUE. I'LL RATE IT A PIOR OF 2. I THINK THE AIRPLANE IS CONTROLLABLE, ACCEPTABLE, BUT IT IS UNSATISFACTORY. IT NEEDS IMPROVEMENT. I WOULD LIKE TO BE ABLE TO HAVE LIGHTER FORCES AND MAINTAIN STRUCTURAL PROTECTION. I'LL RATE IT A-3.5.
...ORMAL ACCELERATION CONTROL ...BILITY WERE PRETTY GOOD. I ...THAT I DIDN'T HAVE REAL TIGHT ...UT IT WASN'T TOO BAD.	I HAD A VERY SLIGHT TENDENCY TO OVERSHOOT IN THE STEP TRACKING TASK. IN THE RANDOM INPUT TASK I HAD A LITTLE TROUBLE KEEPING UP WITH THE CHANGE IN THE SIGNAL AND FELT I WAS ALWAYS JUST A LITTLE BEHIND. I FOUND MYSELF BOBBLING THE AIRCRAFT A LITTLE BIT AROUND THE TRIM POINT. IF I ADJUSTED MY GAIN I COULD REDUCE THE BOBBLING TENDENCY BUT THE OVERALL TRACKING ACCURACY WOULD GO DOWN.	THE RANDOM DISTURBANCES AFFECTED THE AIRPLANE MODERATELY.	THE AIRCRAFT HAS GOOD DAMPING, REASONABLE RESPONSIVENESS, AND A FAIRLY GOOD TRACKING CAPABILITY.	I HAD THE FEELING THAT I HAD TO FORCE THE AIRPLANE JUST A LITTLE TO GET THE RESPONSE I WANTED IN TRACKING. FOR SMALL AMPLITUDE INPUTS THERE WAS A TENDENCY TO OVERSHOOT SLIGHTLY. THE STEADY STATE STICK FORCES SEEMED A LITTLE ON THE HIGH SIDE BECAUSE I HAD TO COMPROMISE BETWEEN GOOD STICK FORCES AND CONTROLLABILITY.	THE PIO RATING IS A 2. THERE IS A SLIGHT BOBBLING TENDENCY. THE AIRPLANE IS CONTROLLABLE, ACCEPTABLE AND SATISFACTORY. THERE ARE SOME MILDLY UNPLEASANT CHARACTERISTICS SO I'LL RATE IT A-3.
...D NORMAL ACCELERATION CONTROL ...RE GOOD	THERE WAS A SLIGHT TENDENCY TO OVERCONTROL IN THE STEP TRACKING TASK. IT DOES SEEM THOUGH THAT I CAN GET FROM ONE POINT TO ANOTHER VERY RAPIDLY AND WITH JUST A MINOR CORRECTION ZERO OUT THE PITCH ATTITUDE ERROR. THE TENDENCY TO OVERCONTROL WAS A LITTLE MORE NOTICEABLE IN THE RANDOM INPUT TASK.	THE RANDOM DISTURBANCE AFFECTED THE AIRCRAFT MODERATELY. I COULD CONTROL THE LARGE AMPLITUDE DISTURBANCES TO SOME EXTENT AND I COULD CUT CUT DOWN THE OPEN-LOOP EXCURSIONS IN PITCH SO THE CONTROL WASN'T TOO BAD.	I THINK THE PITCH RESPONSE AND THE DAMPING WERE GOOD. THE STICK FORCES I PICKED WERE REASONABLY GOOD.	NO COMMENTS.	THERE WAS A SLIGHT TENDENCY TOWARDS PIO'S WHEN YOU FLY IT VERY TIGHTLY. I'LL RATE IT A PIOR OF 1½. THE AIRPLANE IS CERTAINLY CONTROLLABLE, ACCEPTABLE, SATISFACTORY, GOOD, AND WELL-BEHAVED. I'LL RATE IT A-2.
...D NORMAL ACCELERATION CONTROL ...EXCEPT FOR THE TENDENCY TO	ON THE STEP ATTITUDE TRACKING, I WOULD OVERSHOOT A LITTLE WHILE CANCELLING OUT THE ERROR SIGNAL. THE INITIAL RESPONSE SEEMED TO BE A LITTLE ABRUPT FOR A LARGER STEP. I HAD A TENDENCY TO OVERDRIVE THE AIRPLANE A LITTLE. IN THE RANDOM INPUT TRACKING TASK I THINK THE TENDENCY TO WOBBLE WAS EVEN MORE NOTICEABLE.	THE AIRCRAFT HAS A PRETTY HARD RIDE IN THE PRESENCE OF THE RANDOM NOISE INPUTS. THE AIRPLANE RESPONDED QUITE A BIT TO THE INPUTS IN THE HIGH FREQUENCY RANGE. THERE ARE SOME PRETTY SHARP MOTIONS INVOLVED, MUCH LIKE YOU'D SEE IN CLEAR AIR TURBULENCE. THE TRACKING UNDER THESE CONDITIONS IS FAIRLY DIFFICULT.	I THINK IT IS A RESPONSIVE AIRPLANE AND IT IS WELL DAMPED.	I GET THE FEELING THAT IT IS EASY TO OVERDRIVE THE AIRPLANE AND THERE IS A TENDENCY TO WOBBLE DURING TIGHT TRACKING TASKS.	THERE IS A TENDENCY TO INDUCE OSCILLATIONS BUT THEY CAN BE ELIMINATED BY PILOT TECHNIQUE. I'LL RATE IT A 2. I HAVE ENOUGH OBJECTIONS TO THE AIRPLANE TO SAY IT'S NOT A GOOD AIRPLANE. IT'S JUST A LITTLE TOO SNAPPY. I'LL RATE IT AN A-3.

B

TABLE IV-VII PILOT COMMENT SUMMARY, PILOT A, $\frac{F_{EW}}{n_z}$ SELECTED BY PILOT

FLIGHT NO.	ω_{SP} RAD/SEC	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_z}$ LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
006	3.33	.60	5	1.5	THE AIRPLANE'S RESPONSE IS SLOW INITIALLY; YOU HAVE A LOT OF STICK TRAVEL. YOU DON'T GET A GOOD FEELING FOR WHERE THE g IS GOING TO GO.	THE STICK FORCES WERE SELECTED TO PREVENT OVER STRESSING THE AIRPLANE IN A SYMMETRICAL PULL-UP. HOWEVER, THEY DIDN'T FEEL TOO UNREASONABLE IN THE STEADY STATE. THE STICK DISPLACEMENTS WERE VERY NOTICEABLE. THE PILOT GETS A SPONGY FEELING IN THE WHEEL.	52.1	THERE IS A DEFINITE LAG BETWEEN THE TIME THE STICK IS DEFLECTED AND WHEN THE RESPONSE STARTS TO APPEAR TO THE PILOT. ONCE THE RESPONSE DOES START, IT LOOKS ALMOST EXPONENTIAL. THE AIRPLANE'S FINAL RESPONSE IS VERY STEADY.	THE PITCH ATTITUDE SEEMS TO LEAD THE g. THERE IS A SLIGHT DELAY FOLLOWING THE INPUT THEN THE g SEEMS TO BUILD UP MORE RAPIDLY THAN YOU WOULD EXPECT FOR THE AMOUNT OF PITCH RATE THAT YOU GET. THIS "g-PHASING" GIVES ME LESS PRECISE CONTROL THAN I WOULD LIKE.	THERE WAS A TENDENCY TO OVERCONTROL ATTITUDE TRAC[illegible]G TASKS BECAUSE OF SLUGGISH OR LAGGING RESPONSE. IT [illegible] ALMOST IMPOSSIBLE TO STAY ON THE [illegible] IN THE RANDOM INPUT TASK. THE AIRP[illegible] IS SLOW IN GETTING GOING, SO WHEN [illegible] WOULD START TO MOVE THE NOSE BY OVE[illegible]TROLLING, I'D OVERSHOOT.
008	5.10	.54	2	1	I THOUGHT THAT THE AIRPLANE IN GENERAL WAS QUITE WELL BEHAVED. I WAS VERY PRECISE ON THE TRACKING TASK; I COULD MAKE VERY SMALL CORRECTIONS AND REALLY STAY ON THE TARGET VERY EASILY. THE ONLY THING NOT QUITE TO MY LIKING IS THIS TENDENCY TOWARDS A SPONGY FEELING IN THE CONTROLS. THERE ARE VERY DEFINITE AND NOTICEABLE STICK MOTIONS. I DON'T THINK THIS WAS DETRACTING TOO MUCH FROM THE OVERALL EVALUATION, BUT IT WAS THERE, AND IT WAS NOTICEABLE. NO PROBLEMS IN TRIMMING; AIRSPEED CONTROL WAS GOOD. NO PROBLEM WITH ALTITUDE CONTROL. NOTHING BAD TO SAY ABOUT LONGITUDINAL CONTROL IN TURNS EXCEPT THAT I GOT THAT SPONGY FEELING WHEN I PUT THE g ON IN THE TURN. CLIMBING AND DESCENDING TURNS SHOWED NO PROBLEMS.	THE STICK FORCES WERE SELECTED PRIMARILY FOR STRUCTURAL PROTECTION DURING SYMMETRICAL PULL-OUTS. I DIDN'T FEEL THAT THIS FORCE WAS TOO BAD FOR REGULAR MANEUVERING. I DON'T THINK YOU WOULD BE WORKING TOO HARD AND I DON'T THINK THERE WOULD BE ANY TENDENCY TO OVERSTRESS THE AIRPLANE. I COULD SEE AND FEEL THE STICK DISPLACEMENTS WITH THIS CONFIGURATION. I HAVE A SPONGY FEELING IN THE CONTROL.	51.7	THE RESPONSE SEEMS TO BE SLIGHTLY DELAYED INITIALLY. I'M CERTAINLY AWARE OF PULLING BACK ON THE STICK AND HAVING SOME STICK MOTION BEFORE THE RESPONSE STARTS. HOWEVER, WHEN THE RESPONSE DOES START, THE g IS RIGHT ON THERE AS SOON AS THERE'S ANY MOTION OF THE NOSE. I DIDN'T FEEL THIS WAS DETRIMENTAL. AS A MATTER OF FACT, IF YOU'RE NOT DOING ANYTHING VERY RAPIDLY IT GAVE YOU A REAL PRECISE RESPONSE. YOU COULD PULL UP AND STOP VERY QUICKLY. THE FINAL RESPONSE WAS GOOD WITH NO TENDENCY TO BOBBLE OR OSCILLATE.	PITCH ATTITUDE CONTROL IS GOOD WHILE DOING TIGHT TRACKING OR MAKING SMALL CORRECTIONS IN THE NORMAL ACCELERATION CONTROL FOR THE HIGHER g MANEUVERS, YOU GET A SPONGY FEELING IN THE CONTROLS A LITTLE BI[illegible] BEFORE THE MOTION STARTS. ONCE YOU'RE INTO THE g THINGS FEEL REAL NICE AND STEADY.	THE ATTITUDE TRACKING TASKS DIDN'T PRESENT ANY PROBLEMS. I FELT THAT [illegible] DOING A FAIRLY GOOD JOB AND CERTA[illegible] MY PERFORMANCE WAS AS GOOD AS COUL[illegible] EXPECTED.
005	10.2	.66	2.5	1	THIS IS QUITE A NICE FEELING AIRPLANE. IT'S VERY SOLID, FAIRLY RESPONSIVE BUT NOT OVERLY FAST NOR TOO SLOW. THE THING I ESPECIALLY LIKE IS THE TRACKING CAPABILITY. THERE'S NO TENDENCY TO BOBBLE AT ALL. YOU CAN MAKE SMALL CORRECTIONS AND STOP IT RIGHT WHERE YOU WANT TO. TRIMABILITY AND AIRSPEED CONTROL ARE GOOD. ALTITUDE CONTROL WAS NO SWEAT AT ALL. ALTITUDE CONTROL WAS GOOD. LONGITUDINAL CONTROL IN TURNS WAS OKAY EXCEPT THAT IT SEEMED TO ME THAT THE STICK FORCES IN THE TURNS WERE A LITTLE HEAVY.	I CHOSE THE STICK FORCE PER g ON THIS CONFIGURATION. I PICKED IT IN ORDER TO SATISFY THE STRUCTURAL PROTECTION SITUATION IN A SYMMETRICAL PULL-OUT. THE STICK FORCE THAT I PICKED WAS HEAVIER THAN I LIKE BECAUSE YOU HAVE TO WORK TOO HARD, BUT I FELT I HAD TO HAVE IT HEAVY TO HAVE g PROTECTION. I ALSO FELT THAT THE STICK IS A LITTLE MORE "SPONGY" THAN I LIKE. I FEEL THAT I GET A DEFINITE STICK DISPLACEMENT BEFORE THE AIRPLANE RESPONDS. I GET MORE STICK TRAVEL THAN I WOULD EXPECT.	94.5	THE INITIAL RESPONSE IS VERY PRECISE. IT'S A VERY PRECISE AIRPLANE AND I FEEL THAT I HAVE GOOD CONTROL BOTH IN THE INITIAL AND IN FINAL RESPONSES. WHEN YOU'RE LOOKING FOR A GREATER g IN A TURN THE AIRPLANE DOES SEEM TO FEEL A LITTLE STIFF. IT'S A LITTLE HEAVY BECAUSE OF THE STICK FORCE THAT I PICKED.	PITCH ATTITUDE CONTROL IS GOOD WHEN YOU'RE MAKING SMALL CORRECTIONS. THERE'S NO TENDENCY TO BOBBLE. IT FEELS VERY PRECISE. YOU CAN STOP IT WHERE YOU WANT. NORMAL ACCELERATION CONTROL FEELS HEAVY IN THE TURNS, ALTHOUGH I CAN HOLD IT VERY READILY. THE g CONTROL IN THE PULLUP IS SUCH THAT I DON'T THINK I WOULD OVER g THE AIRCRAFT. HOWEVER YOU MAY NOT ALWAYS GET THE g THAT YOU EXPECT. THERE WAS THIS TENDENCY FOR THE g TO SORT OF SLIP IN A LITTLE BIT MORE THAN YOU MIGHT WANT.	MY PERFORMANCE IN THE ATTITUDE TRA[illegible] TASK WAS VERY GOOD. WITH THIS AIRP[illegible] YOU CAN VERY PRECISELY GET TO WHER[illegible] YOU WANT TO GO. THERE IS NO TENDE[illegible] BOBBLE AROUND. I DON'T THINK I COU[illegible] HAVE DONE A BETTER JOB WITH ANY OT[illegible] CONFIGURATION.
004	13.5	.73	3	1	THE AIRPLANE IS QUITE PRECISE, FAIRLY RESPONSIVE, THE DAMPING IS GOOD AND THERE IS NO TENDENCY TO BOBBLE AROUND. I NOTICE THE PHASING DIFFERENCE BETWEEN THE PITCH RATE AND G, THE G SEEMS TO COME ON RIGHT AWAY BUT IT DOESN'T REALLY BOTHER ME.	THE STICK FORCES WERE DETERMINED BY THE FORCE LEVEL THAT I FELT GAVE ME STRUCTURAL PROTECTION IN A SYMMETRICAL PULL OUT. THE FORCES ARE PROBABLY A LITTLE HEAVY IN A STEADY STATE TURN BUT I DON'T THINK YOU'RE APT TO OVERSTRESS THE AIRPLANE. I DO FEEL THAT I HAVE NOTICABLE STICK DISPLACEMENTS WHEN I MANEUVER THE AIRPLANE. THE WHEEL IS BEGINNING TO FEEL A LITTLE "SPONGY" IN THE SENSE THAT I FEEL I'M GETTING MORE MOTION THAN I WOULD EXPECT TO SEE TO MAKE THE THING FEEL REAL PRECISE. IT REALLY DOESN'T DETRACT FROM YOUR MANEUVERING, IT JUST DOESN'T SEEM TO ME AS NICE AS WHAT I'VE SEEN BEFORE.	90.2	THE INITIAL RESPONSE IS GOOD. IT IS VERY, VERY QUICK. THE g TENDS TO COME ON ALMOST RIGHT AWAY. I CAN VERY ACCURATELY GET THE AIRPLANE GOING AND STOP IT VERY PRECISELY WHEN I WANT TO.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WERE VERY GOOD. THE LARGER STICK TRAVEL DOES NOT SEEM TO DETRACT FROM THE OVERALL CAPACITY.	THE TRACKING CAPABILITY IS VERY GOOD[illegible] FELT WHEN I WAS TRACKING THAT I COU[illegible] REALLY HAVE DONE BETTER.

SELECTED BY PILOT GROUP II ($1/T_{\theta_2} \approx 2.65$, $n_z/\alpha \approx 56.2$ g/RAD, $\zeta_{sp} \approx 0.7$, $V_T = 685$ FT/SEC)

	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATING
...D THE g ...DE THE INPUT ...E RAPIDLY ...OUNT OF "g-PHASING" THAN I WOULD	THERE WAS A TENDENCY TO OVERCONTROL IN THE ATTITUDE TRACKING TASKS BECAUSE OF THE SLUGGISH OR LAGGING RESPONSE. IT WAS ALMOST IMPOSSIBLE TO STAY ON THE NEEDLE IN THE RANDOM INPUT TASK. THE AIRPLANE IS SLOW IN GETTING GOING, SO WHEN I WOULD START TO MOVE THE NOSE BY OVERCONTROLLING, I'D OVERSHOOT.	THE RANDOM DISTURBANCES DID NOT AGITATE THE AIRPLANE VERY MUCH. THE TRACKING PERFORMANCE WAS NOT AFFECTED MUCH.	ONCE THE AIRCRAFT IS ON TARGET WITH NO CORRECTIONS TO MAKE, IT IS VERY STEADY. IT SEEMS TO RIDE WELL IN TURBULENCE.	THE SLUGGISH OR LAGGING RESPONSE, THE SPONGY FEEL IN THE CONTROL AND THE TENDENCY TO OVERCONTROL ARE OBJECTIONABLE.	UNDESIRABLE MOTIONS TEND TO OCCUR WHEN THE PILOT ATTEMPTS TIGHT CONTROL. I'LL RATE IT A PIOR OF 1.5. I'LL RATE THE AIRPLANE UNSATISFACTORY. I WOULD LIKE TO SEE ALL OF THE OBJECTIONABLE FEATURES FIXED. I'LL CALL IT AN A-5.
...ILE DOING CORRECTIONS ...OL FOR THE SPONGY FEELING ...FORE THE ...N THE g ...Y.	THE ATTITUDE TRACKING TASKS DIDN'T PRESENT ANY PROBLEMS. I FELT THAT I WAS DOING A FAIRLY GOOD JOB AND CERTAINLY MY PERFORMANCE WAS AS GOOD AS COULD BE EXPECTED.	I DIDN'T SEE ANY PARTICULAR CONTROL PROBLEMS DUE TO THE RANDOM DISTURBANCES.	THE AIRPLANE WAS VERY PRECISE AND SOLID IN THE TRACKING TASKS; NO TENDENCY TO BOBBLE AROUND AND NO OSCILLATING TENDENCY.	THE ONLY OBJECTION I HAVE IS THIS FEELING TOWARDS A LITTLE SPONGY CONTROL.	THERE WAS NOTHING TO CAUSE ME TO RATE THIS OTHER THAN A 1 FOR PIO. CERTAINLY THE AIRPLANE IS SATISFACTORY. I FELT IT WAS GOOD ENOUGH THAT NOTHING REALLY HAD TO BE FIXED. BECAUSE OF THE SPONGY FEELING, I'LL RATE IT AN A-2.
...WHEN YOU'RE ...E'S NO ...ERY PRECISE. ... NORMAL ...Y IN THE ...ERY READILY. ...OUCH THAT I ...AIRCRAFT: ...THE g THAT ...DENCY FOR THE ...UT MORE THAN	MY PERFORMANCE IN THE ATTITUDE TRACKING TASK WAS VERY GOOD. WITH THIS AIRPLANE YOU CAN VERY PRECISELY GET TO WHERE YOU WANT TO GO. THERE IS NO TENDENCY TO BOBBLE AROUND. I DON'T THINK I COULD HAVE DONE A BETTER JOB WITH ANY OTHER CONFIGURATION.	I FELT THAT MY PERFORMANCE IN THE PRESENCE OF THE RANDOM DISTURBANCES WAS DEPENDENT ON WHAT I COULD RIDE THROUGH WITH THE AIRPLANE. I DIDN'T FEEL THAT THE DYNAMICS OF THE AIRPLANE IN THE PRESEGCE OF THE DISTURBANCE WERE CAUSING ME EXTRA PROBLEMS.	THIS IS A VERY PRECISE AIRPLANE: NO TENDENCY TOWARDS ANY OSCILLATIONS OF ANY SORT; VERY PRECISE IN MAKING SMALL PITCH CORRECTIONS.	MY ONLY OBJECTION TO THIS CONFIGURATION IS THE STICK FORCE I PICKED FOR g PROTECTION IS A LITTLE LARGER THAN I LIKE FOR NORMAL MANEUVERING, BUT AGAIN THIS IS NOT OVERPOWERING. IT JUST MEANS YOU HAVE TO WORK A LITTLE HARDER.	THERE IS CERTAINLY NO TENDENCY TOWARDS PIO. I WOULD RATE IT A 1. THE AIRPLANE IS CERTAINLY SATISFACTORY; I WOULD NOT HAVE ANYTHING WORKED ON. HOWEVER, BECAUSE OF THE COMPROMISE THAT I HAD TO MAKE WITH THE STICK FORCES FOR g PROTECTION, I WOULD SAY THE AIRPLANE COULD BE IMPROVED. I'LL RATE IT A-2½.
...ERATION ...NDER ...ETRACT	THE TRACKING CAPABILITY IS VERY GOOD. I FELT WHEN I WAS TRACKING THAT I COULDN'T REALLY HAVE DONE BETTER.	IN THE PRESENCE OF THE RANDOM DISTURBANCE THIS WAS THE MOST JOSTLING AROUND I FELT. HOWEVER, I COULD TEND TO SMOOTH OUT THE RIDE AND TRACK REASONABLY WELL	THE GOOD FEATURES ARE THAT IT IS A VERY SOLID FEELING AIRPLANE, VERY RESPONSIVE WITH NO TENDENCY TO BOBBLE AROUND.	NO OBJECTIONABLE FEATURES EXCEPT THAT I WOULD SAY THAT THIS IS HIGHER THAN TYPICAL STICK TRAVEL THAT I APPEAR TO HAVE WHEN I'M INITIATING A MANEUVER. IT TENDS TO MAKE THE CONTROL FEEL A LITTLE BIT SPONGY BUT IT'S REALLY NOT OBJECTIONABLE.	THERE IS NO TENDENCY TO INDUCE ANY PILOT OSCILLATIONS. THE AIRPLANE IS CERTAINLY SATISFACTORY AND QUITE GOOD IN TRACKING. I WILL RATE IT A LOW SATISFACTORY BECAUSE OF THE SPONGY FEELING IN THE STICK. YOU DON'T SEEM TO HAVE QUITE AS GOOD A FEEL AS YOU WOULD LIKE.

B

TABLE IV-VIII PILOT COMMENT SUMMARY, PILOT B, $\frac{F_{EW}}{n_g}$ SELECTED BY PIL

FLIGHT NO.	ω_{SP} RAD/SEC	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{EW}}{n_g}$ LB/g	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
901	3.16	.62	5.5	2	I DIDN'T LIKE THIS CONFIGURATION. THE STICK FORCES APPEARED TO BE QUITE LIGHT AND STICK MOTIONS SEEMED SORT OF HIGH. THE AIRPLANE SEEMED TO WANT TO "DIG IN" AFTER AN INPUT WAS APPLIED. MY OVERALL FEELING WAS THAT I DIDN'T HAVE VERY TIGHT CONTROL OF THE ATTITUDE OF THE AIRCRAFT.	I ENDED UP WITH WHAT I CONSIDER MODERATE STICK FORCES. I OBJECTED TO PRIMARILY THE COMBINATION OF STICK FORCE AND STICK DISPLACEMENT THAT I HAD. IT SEEMED THAT THE DISPLACEMENTS WERE RATHER LARGE.	52.3	THE INITIAL RESPONSE IS TOO SLUGGISH AND THE FINAL RESPONSE IS NOT TOO BAD, PROBABLY FAIR.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL I THOUGHT WERE POOR.	IN THE STEP INPUT TRACK LARGE STEPS, IT WAS OBV PLANE WAS VERY SLOW RES FORCE THE AIRPLANE TO D PONSE THEN YOU GET THE ARE OVERDRIVING IT AND A BIT. THERE WAS NO QUE PLANE WAS VERY SLUGGIS MAKE SOME RATHER LARGE TRACKING TASKS. THIS W NOTICEABLE IN THE RANDO
899	5.34	.55	3	1.5	I THINK THE OVERALL FEEL IS QUITE GOOD. I PICKED THE STICK FORCES A LITTLE LIGHTER THAN THEY MAYBE SHOULD HAVE BEEN.	I THINK I PICKED THE STICK FORCES SLIGHTLY ON THE LIGHT SIDE. JUST A LITTLE MORE FORCE MAY HAVE MADE ME FEEL A LITTLE BETTER BECAUSE I POSSIBLY WOULDN'T OVERSTRESS THE AIRPLANE ON THE OTHER HAND, FOR MANUEVERING. I THINK THE FORCES COULD HAVE BEEN SLIGHTLY LIGHTER. THE STICK DISPLACEMENTS WERE A LITTLE EXCESSIVE, BUT NOT REALLY DETRIMENTAL TO THE OVER ALL FEEL.	30.1	THE INITIAL RESPONSE MAY BE SLIGHTLY ABRUPT, BUT NOT VERY MUCH SO. I FOUND MYSELF MAKING PRETTY RAPID INPUTS, ESPECIALLY IN THE NEGATIVE g DIRECTION. THIS GAVE ME THE FEELING THAT THE INITIAL RESPONSE WAS SLIGHTLY ABRUPT. THE FINAL RESPONSE FELT COMFORTABLE AND I THINK IT IS JUST ABOUT RIGHT FOR THIS CLASS AIRCRAFT.	PITCH ATTITUDE CONTROL WAS PRETTY GOOD. NORMAL ACCELERATION I THOUGHT I COULD CONTROL WELL. THERE IS SOME TENDENCY TO OVERSHOOT FOR VERY SMALL INPUTS, BUT NOT VERY MUCH.	IN THE STEP ATTITUDE T A TENDENCY TO BOBBLE A VERY MUCH. IN THE RAND TASK, I HAD TO REDUCE DO A GOOD JOB OF TRACK PUTS. I HAD A TENDENCY FOR BIG ATTITUDE CHANG IT A LITTLE FOR SMALL DIDN'T FEEL AS THOUGH TRACKING AND I THOUGHT THE CONTROLS A LITTLE
904	7.8	.73	3.5	1.5	THIS WAS NOT A BAD AIRPLANE, BUT IT WASN'T OPTIMUM BY ANY MEANS.	I HAD TO CHOOSE THE STICK FORCE TO KEEP THE INITIAL RESPONSE DOWN. THE FORCES I FINALLY CHOSE WERE SOMEWHAT ON THE HEAVY SIDE IN THE STEADY STATE BUT THEY SEEMED TO BE FAIRLY COMFORTABLE FOR THE SMALL AMPLITUDE INPUTS IN THE WINGS-LEVEL CONDITION. THE STICK FORCES SEEMED MODERATE.	37.1	THE INITIAL RESPONSE WAS MAYBE A LITTLE ABRUPT. THE FINAL RESPONSE WAS OKAY NO OSCILLATORY TENDENCY.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WERE FAIR TO GOOD.	IN THE STEP INPUT ATTIT IT SEEMED THAT I HAD TO LARGE INPUTS BUT I DIDN DENCY TO OVERSHOOT. I D FEELING AT TIMES THAT I ABRUPT. THE RANDOM INPU LITTLE MORE TROUBLE WHE SOME TENDENCY TO OVERSH PIN DOWN THE ATTITUDE W INPUTS WAS A LITTLE MORE WITH THE STEP INPUTS.
902	8.8	.77	4	2	MY GENERAL IMPRESSION OF THE AIRCRAFT WAS THAT IT IS JUST FAIR AND HAS SOME OBJECTIONABLE FEATURES. I HAD SOME DIFFICULTY TRYING TO DETERMINE WHAT IT WAS THAT WAS GIVING ME TROUBLE.	I HAD A LITTLE DIFFICULTY PICKING THE STICK FORCES FOR THIS CONFIGURATION. I THINK THE STEADY-STATE FORCE MAY BE A LITTLE HEAVY, BUT ON THE OTHER HAND, I CAN GENERATE 2 INCREMENTAL g'S RATHER RAPIDLY. I GET THE IMPRESSION THAT THE STICK FORCES ARE INITIALLY A LITTLE LIGHT BUT AS YOU REACH THE STEADY STATE, THEY SEEM A LITTLE TOO HEAVY. THE FORCES JUST DIDN'T SUIT ME, BUT I CAN'T REALLY PUT MY FINGER ON THE DIFFICULTY.	44.1	THE INITIAL RESPONSE FOR LARGE AMPLITUDE INPUTS WAS A LITTLE TOO SENSITIVE. THE FINAL RESPONSE WASN'T TOO BAD, BUT IT MADE THE STICK FORCES FEEL A LITTLE BIT ON THE HEAVY SIDE.	PITCH ATTITUDE CONTROL AND TRACKING CAPABILITY WASN'T TOO BAD. I WOULD MAKE SOME RATHER LARGE INPUTS AND STILL STOP THE AIRPLANE REASONABLY CLOSE TO WHERE I WANTED. I HAD A TENDENCY TO OVERSHOOT A LITTLE IN NORMAL ACCELERATION CONTROL FOR MODERATE ACCELERATIONS.	DURING THE STEP ATTITU I FOUND MYSELF MAKING R INPUTS. THIS WAS PARTIC IN THE NEGATIVE G DIREC DOM INPUT TASK MY PERF FAIR. IT DID SEEM TO ME MOTIONS WERE A LITTLE B NORMAL AND I DID HAVE S OVERSHOOT.
904	13.5	.65	4	2.5	THE AIRPLANE OBVIOUSLY HAD A HIGH FREQUENCY SHORT PERIOD. I GOT THE IMPRESSION THAT THE SMALLER θ TRACKING MANUEVERS WERE A LITTLE HARDER THAN THE LARGER AMPLITUDE MANUEVERS.	THE BIG PROBLEM IN CHOOSING THE STICK FORCE WAS TO KEEP DOWN THE INITIAL RESPONSE OF THE AIRPLANE. THE FINAL STICK FORCE THAT I CHOSE WAS POSSIBLY A LITTLE ON THE HEAVY SIDE IN A TURN, BUT IT WAS QUITE EASY TO GET 2 INCREMENTAL g IN A WINGS-LEVEL CONDITION. WITH A LIGHTER FORCE I FELT THE AIRCRAFT RESPONSE WAS MUCH TOO ABRUPT INITIALLY. SO I HAD TO COMPROMISE ON THE FORCE. STICK DISPLACEMENTS FELT MODERATELY LARGE.	32.3	THE INITIAL RESPONSE, I FELT, WAS SOMEWHAT SNAPPY FOR THIS CLASS AIRPLANE. THE FINAL RESPONSE WASN'T TOO BAD. I HAD A VERY SLIGHT TENDENCY TO OVERSHOOT BUT I COULD MAINTAIN A STEADY STATE TURN QUITE WELL.	THE PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WAS FAIR. I HAD THE FEELING THAT THE RESPONSE WAS TOO ABRUPT INITIALLY BUT THEN AT OTHER TIMES I FELT I HAD TO PUSH THE AIRPLANE AROUND OR OVERDRIVE IT.	NO COMMENT

A

..., $\frac{F_{EW}}{n_z}$ SELECTED BY PILOT GROUP II ($1/T_{\theta_2} \approx 2.65$, $n_z/\alpha \approx 56.2$ g/RAD, $\zeta_{sp} \approx 0.7$, V_T = 685 FT/SEC)

... ATTITUDE ... NORMAL ...ION CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
... NORMAL ACCELERATION WERE POOR.	IN THE STEP INPUT TRACKING TASK FOR THE LARGE STEPS, IT WAS OBVIOUS THAT THE AIRPLANE WAS VERY SLOW RESPONDING. IF YOU FORCE THE AIRPLANE TO SPEED UP THE RESPONSE THEN YOU GET THE FEELING THAT YOU ARE OVERDRIVING IT AND YOU MAY OVERSHOOT A BIT. THERE WAS NO QUESTION THAT THE AIRPLANE WAS VERY SLUGGISH. YOU HAVE TO MAKE SOME RATHER LARGE INPUTS IN BOTH TRACKING TASKS. THIS WAS PARTICULARLY NOTICEABLE IN THE RANDOM INPUT TRACKING.	THE RANDOM DISTURBANCES HAD PRACTICALLY NO EFFECT ON THE AIRPLANE.	THERE IS GOOD DAMPING IN PITCH.	THE SLUGGISH RESPONSE, THE TENDENCY TO OVERDRIVE OR OVERCONTROL THE AIRPLANE, AND THE LARGE STICK MOTIONS ARE ALL OBJECTIONABLE.	UNDESIRABLE MOTIONS DO OCCUR WHEN YOU MAKE AN ABRUPT INPUT, BUT THESE CAN BE ELIMINATED EASILY WITH PILOT TECHNIQUE SO I'LL RATE IT A PIOR OF 2. THE AIRPLANE IS CONTROLLABLE AND YOU COULD DO THE MISSION TO SOME EXTENT ALTHOUGH I THINK IT NEEDS IMPROVEMENT IN ITS RESPONSE. IT IS BETWEEN A-5 AND A-6. I'LL RATE IT A-5.5.
...TROL WAS PRETTY GOOD ... I THOUGHT I COULD ...E IS SOME TENDENCY ...VERY SMALL INPUTS, BUT	IN THE STEP ATTITUDE TRACKING TASK I HAD A TENDENCY TO BOBBLE A LITTLE, BUT NOT VERY MUCH. IN THE RANDOM INPUT TRACKING TASK, I HAD TO REDUCE MY GAIN A LITTLE TO DO A GOOD JOB OF TRACKING THE SMALL INPUTS. I HAD A TENDENCY TO OVERCONTROL FOR BIG ATTITUDE CHANGES AND TO BE BEHIND IT A LITTLE FOR SMALL ATTITUDE CHANGES. I DIDN'T FEEL AS THOUGH I HAD REAL TIGHT TRACKING AND I THOUGHT I HAD TO MOVE THE CONTROLS A LITTLE TOO MUCH.	THE AIRPLANE RESPONDED MODERATELY TO THE RANDOM INPUTS. IT SEEMED TO ME THAT THE STICK FORCES WERE HEAVIER WITH THE RANDOM INPUT APPLIED THAN WHEN IT'S NOT. THIS IS ONLY FOR MANUEVERING FORCES, STEADY STATE FORCES SEEM THE SAME. THE RANDOM DISTURBANCES WOULD MAKE THE PILOT WORK A MODERATE AMOUNT ABOVE AND BEYOND SMOOTH AIR OPERATION.	I THINK THE STICK FORCE GRADIENTS, THE DAMPING RATIO, AND THE TRACKING CAPABILITY WERE ALL GOOD FEATURES.	I HAD A SLIGHT OBJECTION TO THE STICK NOT GRS AND THE SLIGHT BOBBLING OR OR OVERSHOOTING TENDENCY.	THERE IS A VERY SLIGHT TENDENCY TOWARDS PIO. I'LL RATE IT A 1½. THE AIRPLANE IS CONTROLLABLE, ACCEPTABLE, SATISFACTORY, AND IT IS GOOD, WELL BEHAVED. THERE ARE SOME MILDLY UNPLEASANT CHARACTERISTICS SO I'LL RATE IT A-3.
... NORMAL ACCELERATION TO GOOD.	IN THE STEP INPUT ATTITUDE TRACKING TASK IT SEEMED THAT I HAD TO MAKE SOME FAIRLY LARGE INPUTS BUT I DIDN'T SEE ANY TENDENCY TO OVERSHOOT. I DID HAVE THE FEELING AT TIMES THAT I WAS BEING TOO ABRUPT. THE RANDOM INPUT TASK GAVE ME A LITTLE MORE TROUBLE WHERE I DID HAVE SOME TENDENCY TO OVERSHOOT. TRYING TO PIN DOWN THE ATTITUDE WITH THE RANDOM INPUTS WAS A LITTLE MORE OF A CHORE THAN WITH THE STEP INPUTS.	THE RANDOM DISTURBANCE CERTAINLY AFFECTED THE AIRPLANE. IT IS SOMEWHAT OF A PROBLEM TO TRACK WITH IT IN THE PRESENCE OF THE DISTURBANCES.	THE AIRPLANE IS FAIRLY RESPONSIVE AND THERE IS NOT MUCH TENDENCY TO OVERSHOOT OR BOBBLE.	THE MAIN OBJECTION I HAVE IS THAT I HAD TO PICK THE STICK FORCE TOO HEAVY FOR THE STEADY STATE IN ORDER TO KEEP THE INITIAL RESPONSE FROM BEING SO ABRUPT.	OCCASIONALLY I SAW THESE UNDESIRABLE MOTIONS DUE TO THE ABRUPTNESS. I'LL GIVE IT A PIOR OF 1.5. THE AIRPLANE IS CONTROLLABLE, ACCEPTABLE, AND PROBABLY ON THE BORDERLINE BETWEEN SATISFACTORY AND UNSATISFACTORY. I DIDN'T LIKE THE STEADY STATE STICK FORCES, THEY WERE TOO HEAVY. I'LL RATE IT AN A-3.5.
...TROL AND TRACKING ... TOO BAD. I WOULD MAKE ... INPUTS AND STILL STOP ...ABLY CLOSE TO WHERE ... TENDENCY TO OVERSHOOT ... ACCELERATION CONTROL ...ERATIONS	DURING THE STEP ATTITUDE TRACKING TASK I FOUND MYSELF MAKING RATHER LARGE ABRUPT INPUTS. THIS WAS PARTICULARLY NOTICEABLE IN THE NEGATIVE θ DIRECTION. IN THE RANDOM INPUT TASK MY PERFORMANCE WAS PRETTY FAIR. IT DID SEEM TO ME THAT THE STICK MOTIONS WERE A LITTLE BIT LARGER THAN NORMAL AND I DID HAVE SOME TENDENCY TO OVERSHOOT.	THE RANDOM DISTURBANCE AFFECTED THE THE AIRCRAFT MODERATELY. THE AIRPLANE RESPONDED QUITE A BIT TO THE HIGH FREQUENCY CONTENT OF THE DISTURBANCES. THIS GIVES YOU A FAIRLY ROUGH RIDE. IT'S A VERY CHOPPY TYPE RESPONSE. IT'S VERY DIFFICULT TO TRACK IN THE PRESENCE OF THESE DISTURBANCES BECAUSE THE NOSE IS JUMPING AROUND SO RAPIDLY. HOWEVER THE AMPLITUDES OF THE RESPONSE WERE FAIRLY SMALL SO I THINK YOU COULD PROBABLY STILL DO IN-FLIGHT REFUELING.	GOOD DAMPING IN PITCH. REASONABLY GOOD RESPONSE AND FAIR ABILITY TO TRACK.	THE SOFT FEEL THE AIRPLANE HAS FOR SMALL AMPLITUDE INPUTS AND THE HEAVY FEEL IT HAS AT LARGER g. I HAD THE FEELING THAT STICK MOTIONS WERE GIVING ME THE PROBLEMS RATHER THAN STICK FORCES.	THERE IS NO STRONG PIO TENDENCY AT ALL. SOME OVERSHOOTING ESPECIALLY FOR LARGE AMPLITUDES. I'LL CALL IT A-2. THE AIRPLANE WAS ACCEPTABLE, BUT I THINK IT'S UNSATISFACTORY FOR THIS CLASS AIRPLANE. I'D SAY IT HAS MODERATELY OBJECTIONABLE DEFICIENCIES AND IMPROVEMENT IS NEEDED. I COULDN'T GET A STICK FORCE THAT I FELT MATCHED THE AIRPLANE VERY WELL. I CAN'T DECIDE EXACTLY WHAT IT IS THAT NEEDS TO BE FIXED BUT I'LL RATE IT A-4.
... AND NORMAL ACCELERA-...ATION. I HAD THE ...RESPONSE WAS TOO ABRUPT ... AT OTHER TIMES I FELT ... AIRPLANE AROUND OR	NO COMMENT.	THE AIRPLANE WAS AFFECTED A GREAT DEAL BY THE RANDOM DISTURBANCES. I WOULD HAVE SERIOUS DOUBTS ABOUT REFUELING UNDER THESE CONDITIONS. THE AIRPLANE'S PERFORMANCE IS CERTAINLY DETERIORATED BY THE DISTURBANCES.	THE GOOD DAMPING, THE FACT THAT I DON'T THINK I WOULD INADVERTENTLY OVERSTRESS THE AIRPLANE, AND THE INITIAL RESPONSE TO LOW GAIN INPUTS ARE GOOD FEATURES.	THE ABRUPTNESS DURING TIGHT TRACKING TASKS, AND THE FEELING AT TIMES THAT I HAVE TO PUSH THE AIRPLANE AROUND ARE OBJECTIONABLE FEATURES.	THE ABRUPTNESS IN THE INITIAL RESPONSE IS NOT A PIO BUT IT IS CERTAINLY AN UNDESIRABLE MOTION. I'M GOING TO RATE THIS A PIOR OF 2.5. I THINK THE AIRPLANE IS CONTROLLABLE, IT IS ACCEPTABLE, AND IT IS UNSATISFACTORY. THE OBJECTIONS THAT I HAVE AREN'T TOO STRONG SO I'LL RATE IT A-4.

TABLE IV-IX PILOT COMMENT SUMMARY, PILOT B, $\frac{\delta_{E_W}}{n_z}$ VARIED, GROUP I ($1/T_{\theta_2}$

FLIGHT NO.	ω_{sp} $\frac{RAD}{SEC}$	ζ_{sp}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	F_s/n_z	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
800	8.05	.05	1.5	1	I THOUGHT THAT OVERALL THIS IS PROBABLY A VERY GOOD CONFIGURATION FOR THE MISSION. THE ONLY RESERVATION I HAD WAS THAT MAYBE THE STICK FORCES WERE A LITTLE ON THE HIGH SIDE. I'M NOT REALLY SURE OF THIS, HOWEVER, SINCE I GOT INTO BUFFET AT ABOUT 1½ INCREMENTAL g. BUT EVEN THEN, I FELT THAT MAYBE THE FORCES WERE A LITTLE HIGH. THE INITIAL FORCES SEEMED TO BE COMFORTABLE, MAYBE EVEN A LITTLE LIGHT. THE TURNABILITY WAS EXCELLENT. ALTITUDE CONTROL WAS QUITE EASY, VERY GOOD. LONGITUDINAL CONTROL IN TURNS, ENTRIES, MAINTAINING THE TURN, AND RECOVERY I THOUGHT WAS EXCELLENT. I THOUGHT CLIMBING AND DESCENDING TURNS WERE VERY EASY TO MAKE.	THE INITIAL STICK FORCE WAS GOOD. IF ANYTHING IT MAY HAVE BEEN SLIGHTLY LIGHT. STICK DISPLACEMENTS APPEARED TO BE COMFORTABLE. IN SYMMETRICAL PULL-UPS THE STICK FORCE GRADIENT FELT BETTER THAN IT DID IN A STEADY TURN. THE FORCE IN THE TURN WAS JUST ENOUGH HIGHER THAN THAT IN THE SYMMETRICAL PULL-UPS TO MAKE ME THINK IT WAS A LITTLE TOO HEAVY.	37.9 1.00	THE INITIAL RESPONSE WAS QUITE GOOD FOR THIS CLASS AIRPLANE. THERE WAS NO PROBLEM IN MAINTAINING A STEADY STATE, EXCEPT THAT I FELT THE FORCES WERE A LITTLE HIGH.	PITCH ATTITUDE CONTROL WAS GOOD. NORMAL ACCELERATION CONTROL I THOUGHT WAS EXCELLENT.	THE STEP INPUT TRACKING TASK WAS EASY AND I THINK MY OWN PERFORMA QUITE GOOD. THERE WAS A SLIGHT TE TO OVERCONTROL FOR VERY, VERY SM INPUTS. ON THE RANDOM INPUT TRAC FOUND THAT I HAD TO CUT MY GAIN KEEP FROM OVERSHOOTING. I COULD TRACK ACCURATELY, BUT FOR VERY SM ABRUPT INPUTS THERE WAS A TENDEN BOBBLE.
801	9.3	.01	2	1.5	THIS SEEMS TO BE A PRETTY GOOD AIRCRAFT. THE STICK FORCES AND SHORT PERIOD FREQUENCY SEEM TO MATCH WELL FOR THIS CLASS AIRCRAFT. HOWEVER, ON THE TRACKING TASKS THE AIRPLANE SEEMED TO HAVE A SOFT FEEL TO IT. I WOULD SAY THE STICK MOTIONS WERE MODERATE. I DID HAVE A SLIGHT TENDENCY TO OVERSHOOT DURING TRACKING, SO MY OVERALL IMPRESSION IS THAT IT'S A GOOD AIRCRAFT BUT IT COULD BE SLIGHTLY IMPROVED. I HAD NO PROBLEMS IN TURN ENTRY OR MAINTAINING LEVEL TURNS. NO PROBLEM IN CLIMBING OR DESCENDING TURNS. I HAD GOOD CONTROL OF RATE OF CLIMB AND DESCENT.	I THOUGHT THE STICK FORCES WERE QUITE GOOD. THEY MAY EVEN HAVE BEEN SLIGHTLY LIGHT SINCE THE PILOT HAS SOME TENDENCY TO OVERSHOOT WHEN HE'S TRACKING USING VERY HIGH GAINS. STICK DISPLACEMENTS ARE MODERATE.	41.1 1.10	THE AIRPLANE'S INITIAL AND FINAL RESPONSES ARE GOOD.	I HAD VERY GOOD PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL DURING ALL OF THE MANEUVERS. I COULD HOLD A DESIRED g OR CHANGE TO A NEW g LEVEL WITH NO PROBLEM.	I HAD A DEFINITE TENDENCY TO OVE IN THE TRACKING TASKS. HOWEVER, WOULD ONLY OVERSHOOT ONCE AND TH RIGHT ONTO THE DESIRED ATTITUDE NO REAL DIFFICULTY. I WOULD RATE TRACKING AS QUITE GOOD. THE RAND TRACKING INDICATED A LITTLE MORE ICALLY THAT THE PILOT HAD TO ADJ HIS GAIN OR HE WOULD OVERSHOOT. ABLE TO SHAPE MY INPUT AT ONE PO TO KEEP FROM OVERSHOOTING. THE DENCY IS TO KEEP YOUR GAIN UP FA HOWEVER, THUS THE OVERSHOOTING T
804	6.75	.05	2	2	IN GENERAL A PRETTY GOOD AIRPLANE. I CAN'T SEE ANYTHING GROSSLY INADEQUATE ABOUT THIS AIRPLANE. I THINK I WOULD POSSIBLY LIKE TO HAVE THE AIRPLANE A LITTLE MORE RESPONSIVE IN PITCH. I LIKE THE STICK FORCE GRADIENT, ALTHOUGH IT IS SLIGHTLY LIGHT AND THERE IS A SLIGHT TENDENCY TO OVERSHOOT IN THE TRACKING TASKS. THE OVERALL IMPRESSION IS THAT IT IS A GOOD AIRPLANE.	I LIKED THE STEADY STATE STICK FORCE AND IN GENERAL FELT THE FORCES WERE GOOD BUT POSSIBLY FOR THIS CLASS OF AIRCRAFT THEY MIGHT BE JUST A LITTLE ON THE LIGHT SIDE. PROBABLY NOT MUCH BUT SLIGHTLY. BECAUSE OF THE MODERATE SHORT PERIOD FREQUENCY I BELIEVE I HAVE A TENDENCY TO POSSIBLY OVERDRIVE THE AIRPLANE A LITTLE AND THIS GIVES THE THE IMPRESSION OF LARGER STICK MOTIONS. NOT A MAJOR POINT BUT NOTICEABLE. I WOULD SAY THE STICK DISPLACEMENTS ARE MODERATE.	41.1 1.05	I BELIEVE THE INITIAL RESPONSE WAS JUST A LITTLE BIT SLUGGISH AND I HAD A SLIGHT TENDENCY TO OVERSHOOT IN THE FINAL RESPONSE. POSSIBLY I WAS OVERDRIVING THE AIRPLANE A LITTLE BIT BUT THE STEADY STATE WAS OKAY AND THE ABILITY TO CONTROL THE AIRPLANE FOR SMALL AMPLITUDE ACCELERATIONS IN A TURN WAS RATHER GOOD.	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL WASN'T QUITE AS GOOD AS EXPECTED. IF I KEPT MY GAIN DOWN I WAS A LITTLE BIT SLOW IN REDUCING THE TRACKING ERROR TO ZERO AND IF I PICKED MY GAIN UP I HAD A TENDENCY TO OVERSHOOT. THE TRACKING WAS FAIR TO GOOD BUT NOT AS GOOD AS I WOULD LIKE TO SEE IT. I THINK I WOULD HAVE LIKED A MORE RESPONSIVE AIRPLANE. HOWEVER, FOR A MODERATELY LARGE AIRPLANE YOU PROBABLY DON'T WANT TO PUSH IT AROUND QUITE THAT FAST SO IT MIGHT JUST BE OKAY.	IN THE STEP ATTITUDE TRACKING TA HAD SOME DIFFICULTY IN ADJUSTING GAIN SO THAT I COULD REDUCE THE AMPLITUDE ERRORS TO ZERO AND AT SAME TIME NOT OVERSHOOT. I FELT PUSH THE AIRPLANE SOMEWHAT AND HAVE VERY TIGHT CONTROL OF THE T

A

VARIED, GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_z/\alpha \approx 16.5$ g/RAD, $\omega_{sp} \approx 4.0$ RAD/SEC, $\zeta_{sp} \approx 0.7$, V_T = 411 FT/SEC)

...N ...TROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
...G GOOD. NORMAL ...OUGHT WAS EX...	THE STEP INPUT TRACKING TASK WAS QUITE EASY AND I THINK MY OWN PERFORMANCE WAS QUITE GOOD. THERE WAS A SLIGHT TENDENCY TO OVERCONTROL FOR VERY, VERY SMALL INPUTS. ON THE RANDOM INPUT TRACKING, I FOUND THAT I HAD TO CUT MY GAIN DOWN TO KEEP FROM OVERSHOOTING. I COULD STILL TRACK ACCURATELY BUT FOR VERY SMALL, ABRUPT INPUTS THERE WAS A TENDENCY TO BOBBLE.	I DON'T THINK THE AIRPLANE RESPONDED GREATLY TO THE RANDOM INPUTS. I FELT THAT MY ATTITUDE CONTROL WAS GOOD ENOUGH SO THAT I COULD PROBABLY DO IN-FLIGHT REFUELING.	THE AIRCRAFT WAS WELL DAMPED. THE MODERATE SHORT PERIOD FREQUENCY IS COMPATIBLE WITH THIS CLASS AIRCRAFT.	I HAVE A MILD OBJECTION TO THE SLIGHTLY HEAVY STEADY-STATE STICK FORCES AND TO THIS SLIGHT TENDENCY TO BOBBLE FOR SMALL INPUTS.	I DON'T THINK I'LL EVEN CONSIDER THAT SLIGHT BOBBLING TENDENCY IN THE PIO RATING. I'LL RATE IT A 1. FOR THE PILOT RATING I'M DEBATING HOW HEAVILY TO WEIGH THESE MINOR OBJECTIONS. I GUESS I'LL RATE IT A-1½.
...ITUDE AND NORMAL ...NG ALL OF THE DESIRED θ OR ...ITH NO PROBLEM.	I HAD A DEFINITE TENDENCY TO OVERSHOOT IN THE TRACKING TASKS. HOWEVER, I WOULD ONLY OVERSHOOT ONCE AND THEN LOCK RIGHT ONTO THE DESIRED ATTITUDE WITH NO REAL DIFFICULTY. I WOULD RATE THE TRACKING AS QUITE GOOD. THE RANDOM INPUT TRACKING INDICATED A LITTLE MORE GRAPHICALLY THAT THE PILOT HAD TO ADJUST HIS GAIN OR HE WOULD OVERSHOOT. I WAS ABLE TO SHAPE MY INPUT AT ONE POINT TO KEEP FROM OVERSHOOTING. THE GENERAL TENDENCY IS TO KEEP YOUR GAIN UP FAIRLY HIGH HOWEVER. THUS THE OVERSHOOTING TENDENCY.	THE AIRCRAFT ONLY RESPONDED MODERATELY TO THE RANDOM DISTURBANCES. THERE WERE NO UNDESIRABLE CHARACTERISTICS THAT DETRACTED FROM MY TRACKING CAPABILITY ANY MORE THAN WOULD BE EXPECTED FROM NORMAL TURBULENCE.	THE AIRPLANE HAD GOOD DAMPING. GOOD RESPONSE AND GOOD ACCELERATION CONTRO.	THE AIRPLANE'S SLIGHTLY SOFT FEELING IS THE ONLY OBJECTIONABLE FEATURE. I WOULD HAVE LIKED A LITTLE MORE PRECISE CONTROL.	THE AIRPLANE HAS A VERY SLIGHT TENDENCY FOR PIO. I'LL RATE IT A 1½. THE AIRCRAFT IS CONTROLLABLE, ACCEPTABLE, SATISFACTORY FOR THE MISSION, AND IT'S CERTAINLY A GOOD, PLEASANT, WELL-BEHAVED AIRPLANE. I WOULD REQUEST A SLIGHT IMPROVEMENT IN THIS TENDENCY TO OVERSHOOT. I'LL RATE IT A-2.
...CCELERATION ...D AS EXPECTED ...S A LITTLE BIT ...ING ERROR TO ZERO . I HAD A TENDENCY ...WAS FAIR TO ...OULD LIKE TO SEE ...RED A MORE ...D. FOR A MODE- ...ROBABLY DON'T ...E THAT FAST SO	IN THE STEP ATTITUDE TRACKING TASK I HAD SOME DIFFICULTY IN ADJUSTING MY GAIN SO THAT I COULD REDUCE THE LARGE AMPLITUDE ERRORS TO ZERO AND AT THE SAME TIME NOT OVERSHOOT. I FELT I HAD TO PUSH THE AIRPLANE SOMEWHAT AND DIDN'T HAVE VERY TIGHT CONTROL OF THE TRACKING	THE RANDOM DISTURBANCE DISTURBED THE AIRPLANE A LIGHT-TO-MODERATE AMOUNT. TRACKING IN THE PRESENCE OF THE RANDOM DISTURBANCE WAS A LITTLE MORE OF A PROBLEM BUT I CERTAINLY THINK IT WOULD BE ACCEPTABLE AND WOULD ALLOW ME TO TRACK PROPERLY	I THINK THE STICK FORCES ARE COMFORTABLE. POSSIBLY A LITTLE LIGHT BUT GOOD	ALTHOUGH NOT A VERY LARGE OBJECTION, THE SLIGHT AMOUNT OF OVERSHOOTING TENDENCY WHICH I BELIEVE IS COUPLED WITH THE MODERATE SHORT PERIOD FREQUENCY WAS NOTICEABLE	I HAVE TO ADMIT THERE IS SOME TENDENCY TO OVERSHOOT. HOWEVER, I CAN PREVENT THIS BY MERELY CUTTING DOWN MY GAIN. IN GENERAL IT IS A PRETTY GOOD AIRPLANE. IT IS CONTROLLABLE, ACCEPTABLE, A GOOD, PLEASANT WELL-BEHAVED AIRPLANE.

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Table IV-X (Continued) PILOT COMMENT SUMMARY, PILOT A, $\frac{\delta_{FW}}{n_z}$ VARIED GROUP I ($1/T_{\theta_2} \approx 1.29$, n_z/α

FLIGHT NO.	ω_{SP} RAD/SEC	ζ_{SP}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	$\frac{F_{SW}}{n_z}$ LB/G	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
007	6.00	0.1	7	4	THE AIRPLANE IS VERY LIGHTLY DAMPED. THIS TENDS TO CAUSE PROBLEMS WHEN YOU ATTEMPT TIGHT TRACKING. IN TURBULENCE IT'S IMPOSSIBLE.	THE STICK FORCE IS HEAVY. IT GIVES THE AIRPLANE STRUCTURAL PROTECTION AND THE STEADY STATE FORCES ARE NOT OVERLY HEAVY. I DIDN'T NOTICE ANY UNUSUAL STICK DISPLACEMENTS.	67.4	THE INITIAL RESPONSE TO PILOT INPUTS IS NOT TOO BAD. IF YOU'RE MAKING SMALL CORRECTIONS IT'S FAIRLY NICE. HOWEVER, FOR LARGER INPUTS YOU TEND TO GET AT LEAST 3 OR 4 OVERSHOOTS IN THE FINAL RESPONSE BEFORE IT SETTLES DOWN.	THE PITCH ATTITUDE CONTROL IS POOR. WHEN YOU'RE ATTEMPTING TIGHT TRACKING IT'S VERY DIFFICULT TO HOLD THE NOSE WHERE YOU WANT IT. YOU ARE BOBBLING UP AND DOWN ALL THE TIME. IF YOU RELAX A BIT AND ACCEPT 3 OR 4 OVERSHOOTS AND DON'T HAVE TO MAKE ANY MORE INPUTS YOU CAN ESTABLISH A FAIRLY STEADY ATTITUDE. NORMAL ACCELERATION CONTROL IN THE STEADY STATE IS NO PROBLEM.	IN THE ATTITUDE TRACKING TASK THE PERFORMANCE WAS FAIR TO POOR.
			7	4			53.4	COMMENTS AFTER SELECTING F_{SW}/n_z: I PICKED A STICK FORCE THAT I THINK WAS JUST A LITTLE LIGHTER THAN THE ORIGINAL ONE. I'M NOT SURE THOUGH. I MAY HAVE THE SAME ONE.		
006	≈6	≈.1	7	3.5	THERE'S A WORLD OF DIFFERENCE BETWEEN THE PERFORMANCE IN SMOOTH AIR AND THE PERFORMANCE IN TURBULENCE. IF YOU'RE NOT ABRUPT IN SMOOTH AIR THE AIRPLANE IS FAIRLY PRECISE. IF YOU TIGHTENED UP THE CONTROL OR MAKE YOUR INPUT ABRUPT YOU'LL SEE A LITTLE OSCILLATORY TENDENCY.	THE STICK FORCES ARE A LITTLE BIT HEAVY, ESPECIALLY IN THE STEADY STATE. I THINK THEY COULD BE LIGHTENED TO MAKE A BETTER FLYING AIRPLANE. STICK DISPLACEMENTS ARE DEFINITELY NOT CE-ABLE.	≈40	THE INITIAL RESPONSE IS SORT OF A MEDIUM QUICK RESPONSE. THE INITIAL AND FINAL RESPONSES CAN BOTH BE RELATIVELY WELL CONTROLLED BY THE PILOT. IN THE CASE OF THE SHARPER INPUTS YOU SEE A LITTLE BOBBLE IN THE FINAL RESPONSE.	PITCH ATTITUDE CONTROL IS DEGRADED SOMEWHAT BY WHAT APPEARS TO BE AS NOTICEABLE AMOUNT OF STICK TRAVEL BEFORE THE NOSE REACTS TO THE INPUT. THIS IS MOSTLY TRUE OF THE QUICK, SHARP INPUTS. WITH SLOW INPUTS YOU CAN CONTROL THE ATTITUDE FAIRLY WELL. NO PROBLEM HOLDING A STEADY g.	IF YOU TRY TO TRACK VERY TIGHTLY YOU TEND TO BOBBLE. IF YOU EASE UP JUST A LITTLE ON YOUR GAIN YOU CAN STILL TRACK FAIRLY WELL AND NOT GET THE BOBBLES.
			7	3.5				COMMENTS AFTER SELECTING F_{SW}/n_z: I SELECTED A SLIGHTLY LOWER STICK FORCE SO IT WASN'T QUITE SO HARD TO MANEUVER.		
007	10.3	.11	7	4	THIS AIRPLANE IS UNACCEPTABLE. IT'S SO LIGHTLY DAMPED THAT WHEN YOU GET IN TURBULENCE IT'S IMPOSSIBLE TO DO ANYTHING. STICK FORCES ARE A LITTLE ON THE HEAVY SIDE.	STICK FORCES ARE A LITTLE HIGH. YOU'RE WORKING TOO HARD ALL THE TIME. I ALSO GOT THE FEELING THAT I WAS MOVING THE STICK AROUND QUITE A BIT BEFORE THE AIRPLANE RESPONDED.	59.0	THE INITIAL RESPONSE SEEMS TO HAVE A SLIGHT DELAY OR LAG IN RELATION TO THE STICK INPUT. IN THE FINAL RESPONSE YOU HAVE A BOBBLING TENDENCY.	PITCH ATTITUDE CONTROL AND TRACKING CAPABILITY IS SUCH THAT IF YOU'RE TRYING TO MAINTAIN TIGHT CONTROL THE AIRPLANE BOBBLES AROUND QUITE A BIT. IF YOU EASE UP ON YOUR GAIN, THE BOBBLES DECREASE TO THE POINT THAT YOU CAN PUT UP WITH THEM. NORMAL ACCELERATION CONTROL IN THE STEADY STATE IS NOT TOO BAD AS LONG AS YOU EASE UP TO THE DESIRED g.	IN THE ATTITUDE TRACKING TASK IT WAS ALMOST IMPOSSIBLE TO GET AWAY FROM A LITTLE BOBBLE WHEN YOU'RE MAKING SMALL CORRECTIONS. FOR THE STEP TRACKING TASK, ONCE YOU GOT ON THE NEEDLE THE AIRPLANE WOULD SIT RELATIVELY CONSTANT. IN THE RANDOM INPUT TASK THERE WAS A TENDENCY TO BOBBLE AROUND ALMOST CONTINUOUSLY.
			7	4			40	COMMENTS AFTER SELECTING F_{SW}/n_z: I THINK THE STICK FORCE I PICKED WAS A LITTLE LIGHTER THAN THE ORIGINAL. I TRIED TO MAKE IT JUST HEAVY ENOUGH TO GIVE THE AIRPLANE STRUCTURAL PROTECTION.		

VARIED GROUP I ($1/T_{\theta_2} \approx 1.29$, $n/\alpha \approx 16.5$ g/RAD, $\omega_{SP} \approx 4.0$ RAD/SEC, $\zeta_{SP} \approx 0.7$, $V_T = 411$ FT/SEC)

PITCH ATTITUDE AND NORMAL ...LERATION CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
...TUDE CONTROL IS POOR. WHEN ...ING TIGHT TRACKING IT'S VERY ...LD THE NOSE WHERE YOU WANT ...L NG UP AND DOWN ALL THE ...LAX A BIT AND ACCEPT 1 OR ... DOWN ... HAVE TO MAKE ANY ... CAN ESTABLISH A FAIRLY STEADY ...L ACCELERATION CONTROL IN THE ... NO PROBLEM	IN THE ATTITUDE TRACKING TASK THE PERFORMANCE WAS FAIR TO POOR	THE CONTROL IN THE PRESENCE OF RANDOM DISTURBANCES REALLY PUTS THE AIRPLANE "OUT THE WINDOW". IT'S IMPOSSIBLE TO STAY ON A TARGET; YOU'RE JUST ALONG FOR THE RIDE. EVEN IF YOU DON'T MAKE ANY CORRECTIONS AND JUST HOLD WHAT YOU'VE GOT, YOU STILL BOUNCE ALL AROUND THE TARGET. IF YOU GET INTO THE LOOP AND TRY TO MAINTAIN TIGHT CONTROL YOU JUST AGGREVATE THE SITUATION	STICK FORCES ARE GOOD. THE INITIAL RESPONSE IS NOT TOO BAD. SLOW MANEUVERING WITHOUT TURBULENCE IS NOT TOO BAD	IN TIGHT TRACKING YOU'RE BOBBLING ALL OVER THE PLACE. WHEN YOU'RE FLYING IN TURBULENCE IT'S IMPOSSIBLE TO DO ANYTHING	THE OSCILLATIONS DO NOT BECOME DIVERGENT BUT THEY ARE PRESENT ALL THE TIME. I'LL RATE IT A PIOR OF 4. THE AIRPLANE IS CONTROLLABLE BUT BECAUSE OF THE PERFORMANCE IN TURBULENCE IT IS UNACCEPTABLE. I'LL RATE IT A U-7. I WOULD NOT RATE ANYTHING DIFFERENTLY
...CONTROL IS DEGRADED SOME ...PEARS TO BE AS NOTICEABLE ... TRAVEL BEFORE THE NOSE ...PUT. THIS IS MOSTLY TRUE ...ARP INPUTS. WITH SLOW ...CONTROL THE ATTITUDE FAIR ...BLEM HOLDING A STEADY g	IF YOU TRY TO TRACK VERY TIGHTLY YOU TEND TO BOBBLE. IF YOU EASE UP JUST A LITTLE ON YOUR GAIN YOU CAN STILL TRACK FAIRLY WELL AND NOT GET THE BOBBLES	THE CONTROL IN THE PRESENCE OF RANDOM DISTURBANCES KNOCKS THE BOTTOM OUT OF EVERYTHING. IT IS NEXT TO IMPOSSIBLE TO STAY ON A TARGET. YOU ARE JUST ALL OVER THE SKY	NO REAL GOOD FEATURES	THE SMALL BOBBLE WHEN YOU ATTEMPT TIGHT CONTROL. THE EXCESSIVE AMOUNT OF STICK TRAVEL AND THE FACT THAT THE STICK FORCES WERE A LITTLE HEAVY ARE OBJECTIONABLE FEATURES	THIS IS A PIOR OF 3.5 BECAUSE OF THE PERFORMANCE IN THE PRESENCE OF RANDOM DISTURBANCES. THE RESPONSE TO THE RANDOM DISTURBANCES MAKES THE AIRPLANE UNACCEPTABLE. I WOULD LIKE TO SEE THE BOBBLINESS AND THE EXCESSIVE STICK TRAVEL FIXED. I'LL HAVE TO RATE IT U-7 I'LL GIVE IT A PIOR OF 3.5 BECAUSE OF THE PERFORMANCE IN THE PRESENCE OF THE RANDOM DISTURBANCES. I'LL GIVE THE AIRPLANE A U-7. IT IS STILL THE SAME AIRPLANE EXCEPT IT IS NOW A LITTLE EASIER TO FLY WITH THE LIGHTER STICK FORCES
...TROL AND TRACKING CAPA... ...IF YOU'RE TRYING TO ...TROL THE AIRPLANE ...TE A BIT. IF YOU EASE ...THE BOBBLES DECREASE TO ... CAN PUT UP WITH THEM ... CONTROL IN THE STEADY ...AD AS LONG AS YOU EASE ...G	IN THE ATTITUDE TRACKING TASK IT WAS ALMOST IMPOSSIBLE TO GET AWAY FROM A LITTLE BOBBLE WHEN YOU'RE MAKING SMALL CORRECTIONS. FOR THE STEP TRACKING TASK ONCE ... GOT ON THE NEEDLE THE AIRPLANE WOULD ... RELATIVELY CONSTANT. IN THE RANDOM INPUT TASK THERE WAS A TENDENCY TO BOBBLE AROUND ALMOST CONTINUOUSLY	IT IS IMPOSSIBLE TO TRACK OR TO DO ANYTHING IN THE PRESENCE OF THE RANDOM DISTURBANCES. YOU DON'T LOSE CONTROL BUT YOU ARE JUST RIDING THROUGH THIS CONSTANT OSCILLATION. WHEN YOU TRY TO GET INTO THE CONTROL LOOP YOU TEND TO MAKE IT WORSE, BUT IT DOES NOT GO DIVERGENT	NO REALLY GOOD FEATURES	THE BOBBLY TENDENCY. THE NOTICEABLE STICK TRAVEL WHEN YOU TRY TO MANUEVER AND THE PERFORMANCE IN TURBULENCE ARE ALL BAD	BECAUSE OF THE TURBULENCE EFFECT I'M GOING TO RATE IT A PIOR OF 4. THE OVERRIDING FACTOR IN THE PILOT RATING IS THE PERFORMANCE IN TURBULENCE. IT IS CONTROLLABLE BUT YOU JUST CAN'T DO THE MISSION. I'LL RATE IT A U-7 COMMENTS REMAIN THE SAME AND RATINGS REMAIN THE SAME

B

TABLE IV-X PILOT COMMENT SUMMARY, PILOT A, $\frac{\delta_{EW}}{n_z}$ VARIED GROUP I ($1/T_{\theta_2} \approx 1.29$,

FLIGHT NO.	ω_{sp} RAD/SEC	ζ_{sp}	PILOT RATING	PIO RATING	GENERAL COMMENTS	FEEL SYSTEM CHARACTERISTICS	F_{sw}/n_z LB/G	AIRPLANE RESPONSE TO PILOT INPUTS	PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS
[illegible]	1.[illegible]	.077	7	4	THIS IS NOT A VERY GOOD AIRPLANE. IT IS VERY LIGHTLY DAMPED. ONCE YOU'RE ON THE TARGET, THE AIRPLANE FEELS SOLID, BUT WHEN YOU'RE TRYING TO SETTLE ON A PARTICULAR g YOU OVERSHOOT CONSIDERABLY. IT'S A LITTLE HARD TO TRIM BECAUSE YOU HAVE AN OSCILLATORY TENDENCY WHEN YOU TRY TO PIN DOWN AN ATTITUDE. IT WAS VERY DIFFICULT TO MAINTAIN g IN THE TURNS. IF YOU ROLL INTO A TURN QUICKLY YOU HAVE QUITE A TENDENCY FOR PIO.	I REALLY COULDN'T TELL IF THE STICK FORCES WERE ADEQUATE FOR STRUCTURAL PROTECTION BECAUSE I COULDN'T HOLD A STEADY STATE g. THERE WAS NO DISCERNIBLE STICK MOTION	[illegible]	THE INITIAL RESPONSE IS STARTLING BECAUSE THE AIRPLANE IS PITCHING UP AND GETTING g ON BEFORE YOU REALIZE WHAT'S HAPPENING. THIS GIVES YOU A GREAT TENDENCY TO OVER g THE AIRPLANE. IN THE FINAL RESPONSE, IF YOU'RE ON TARGET AND MAKE SMALL SMOOTH CORRECTIONS THE AIRPLANE IS FAIRLY WELL BEHAVED. HOWEVER, IF YOU MAKE ANY ABRUPT INPUTS OR ATTEMPT TO MANEUVER QUICKLY YOU GET AN OSCILLATION GOING	PITCH ATTITUDE CONTROL WAS FAIRLY GOOD IN THE STEADY STATE WITH NO g ON THE AIRPLANE. SMALL CHANGES IN THE NOSE ATTITUDE IN THIS SITUATION FELT FAIRLY REASONABLE. HOWEVER WHEN g IS APPLIED TO THE AIRPLANE, CONTROL BECOMES VERY DIFFICULT. IT WAS IMPOSSIBLE IN A TURN OR IN A SYMMETRICAL PULL-OUT TO MAINTAIN A STEADY g	IT WAS IMPOSSIBLE TO STAY WITH THE NEEDLE ALL THE TIME IN THE STEP TRACKING TASK. I WAS UNABLE TO JUDGE HOW MUCH OVERSHOOT TO ANTICIPATE SO I COULDN'T CHECK THE PITCH RATE TO STOP THE NOSE WHERE I WANTED IT. I HAD TO SETTLE FOR SOMETHING CLOSE. IF I TRIED TO TIGHTEN THE CONTROL LOOP I FOUND THE OSCILLATIONS JUST BECAME LARGER. WITH THE RANDOM INPUTS, YOU JUST COULD NEVER REALLY PIN THE NEEDLE DOWN. YOU WERE CONSTANTLY CHASING IT AND ALWAYS OUT OF PHASE WITH IT
[illegible]	1.[illegible]	.077	6	4	SAME GENERAL COMMENTS AS ABOVE	I PICKED THE STICK FORCE PER G HEAVIER THAN WHAT I HAD BEFORE IN ORDER TO PREVENT OVERSTRESSING THE AIRPLANE. I PICKED THEM HEAVY ENOUGH SO THAT EVEN THOUGH THERE IS A SLIGHT OVERSHOOTING TENDENCY I DON'T THINK YOU WOULD OVERSTRESS THE AIRPLANE.	70	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE
[illegible]	[illegible] SEC. ≈ 4.0	[illegible] SEC. ≈ .1	7	2	IN GROSS AND THE TRACKING PERFORMANCE WAS NOT BAD UNLESS YOU'RE ATTEMPTING REAL TIGHT CONTROL. IF YOU MANEUVER THE AIRPLANE VERY QUICKLY YOU SEE A SLIGHT OSCILLATORY TENDENCY. WHEN YOU'RE GETTING SETTLED INTO THE TRIM ATTITUDE YOU MAY ALSO SEE A LITTLE BOBBLE.	THE STICK FORCES WERE JUST A LITTLE TOO LIGHT. THE OVERSHOOT YOU GET WHEN SUDDEN INPUTS COULD TEND TO MAKE YOU OVERSTRESS THE AIRPLANE. YOU JUST DON'T HAVE THE G PROTECTION I THINK YOU SHOULD HAVE. THERE WERE NO NOTICEABLE STICK DISPLACEMENTS.	[illegible] SEC ≈ 50 ≈ 60	IF THE PILOT IS NOT ABRUPT ON THE CONTROLS THE INITIAL RESPONSE IS FAIRLY NICE. IF YOU TIGHTEN UP ON THE CONTROL, THE INITIAL RESPONSE IS STILL PRETTY GOOD, BUT YOU TEND TO OVERSHOOT OR BOBBLE IN THE FINAL RESPONSE COMMENTS AFTER SELECTING F_{sw}/n_z IN ORDER TO PROVIDE STRUCTURAL PROTECTION I SELECTED HEAVIER STICK FORCES. CONSEQUENTLY THEY ARE NOW A LITTLE TOO HEAVY IN THE STEADY STATE. THIS IS A COMPROMISE I HAVE TO ACCEPT.	PITCH ATTITUDE CONTROL FOR MEDIUM GAIN INPUTS IS NOT TOO BAD. NORMAL ACCELERATION CONTROL IS NOT BAD IF YOU EASE INTO THE DESIRED G. IF YOU PULL TO A VALUE OF G QUICKLY YOU'LL SEE TWO OR THREE OVERSHOOTS BEFORE IT SETTLES DOWN	IN BOTH OF THE TRACKING TASKS, IT WAS NEXT TO IMPOSSIBLE TO STAY ON THE NEEDLE ALL THE TIME. AGAIN, IF YOU TRY TO TRACK VERY TIGHTLY YOU SEE THIS OSCILLATORY TENDENCY
[illegible]	3.[illegible]	.11	7	1.5	THE STICK FORCES ARE JUST TOO HEAVY. YOU CAN'T DO ANYTHING WITH THE AIRPLANE	THE STICK FORCES WERE VERY HEAVY. IT WAS VERY DIFFICULT TO CONTROL THE AIRPLANE. STICK DISPLACEMENTS WERE VERY NOTICEABLE IN THIS CONFIGURATION.	100	THE INITIAL RESPONSE IS VERY SLUGGISH. THE FINAL RESPONSE WAS SLIGHTLY OSCILLATORY	THE SLUGGISH RESPONSE MAKES IT DIFFICULT TO ACQUIRE A PARTICULAR ATTITUDE, BUT ONCE YOU'VE ATTAINED THE DESIRED ATTITUDE, THE AIRPLANE IS FAIRLY SOLID	IN THE ATTITUDE TRACKING TASKS, YOU JUST COULDN'T DO ANYTHING RAPIDLY. IT WAS VERY DIFFICULT TO CHASE THE NEEDLE IN THE STEP INPUT TASK. IN THE RANDOM NOISE TASK IT WAS IMPOSSIBLE TO KEEP THE NEEDLE CENTERED
[illegible]	[illegible]	.1	7	3.5	THERE IS A TENDENCY TO OVER-G THIS AIRPLANE. THE LIGHT STICK FORCES COUPLED WITH THE AIRPLANE DYNAMICS MAKE IT EASY TO OVER-G THE AIRPLANE. THE TRACKING CAPABILITY IS NOT TOO BAD.	THE STICK FORCES ARE SUCH THAT IN A SYMMETRICAL PULL-UP IT WOULD BE VERY EASY TO INADVERTENTLY OVERSTRESS THE AIRPLANE. THEY NEED TO BE HEAVIER. THE STICK DISPLACEMENTS WERE NOT DISCERNIBLE TO ANY GREAT DEGREE.	[illegible].0 [illegible].5	THE INITIAL RESPONSE TO PILOT INPUTS IS REASONABLE. THERE IS A TENDENCY TO BOBBLE OR OVERCONTROL IN THE FINAL RESPONSE COMMENTS AFTER SELECTING F_{sw}/n_z I PICKED A HEAVY STICK FORCE TO GIVE ME G PROTECTION. THE FORCES ARE TOO HIGH IN THE STEADY STATE BUT THAT'S THE [illegible]	PITCH ATTITUDE CONTROL, IF YOU EASE ONTO A TARGET WITH NO SUDDEN LAST MINUTE CORRECTIONS, IS SURPRISINGLY GOOD. YOU MAY SEE SOME TENDENCY TO BOBBLE JUST SLIGHTLY. HOWEVER WHEN YOU TIGHTEN THE LOOP AND MAKE FAST ABRUPT INPUTS, THE OSCILLATIONS GET WORSE. NORMAL ACCELERATION IN THE STEADY STATE IS RELATIVELY STABLE. THERE IS A TENDENCY TO OVER-G THE AIRPLANE IN A PULL-UP WITHOUT REALIZING IT	THE PERFORMANCE DURING THE DISCRETE STEP TRACKING TASK WAS FAIR. IF YOU WOULD PURPOSELY EASE OFF ON YOUR CONTROL GAIN YOU COULD TRACK FAIRLY WELL. YOU WOULD USUALLY GET A BOBBLE ON THE [illegible] THINGS STEADIED OUT. FOR THE RANDOM INPUT TASK THE ONLY THING YOU COULD DO WAS TO JUST REDUCE YOUR GAIN AND TRY TO AVERAGE OUT THE ERRORS.

$\frac{\delta_{EW}}{n_g}$ VARIED GROUP I ($1/T_{\theta_2} \approx 1.29$, $n_3/\alpha \approx 16.5$ g/RAD, $\omega_{sp} \approx 4.0$ RAD/SEC, $\zeta_{sp} \approx 0.7$, V_T = 411 FT/SEC)

PITCH ATTITUDE AND NORMAL ACCELERATION CONTROL	ATTITUDE TRACKING TASKS	CONTROL IN PRESENCE OF RANDOM DISTURBANCES	FAVORABLE FEATURES	OBJECTIONABLE FEATURES	PRIMARY REASONS FOR PILOT RATINGS
...E ATTITUDE CONTROL WAS FAIRLY GOOD ...HE STEADY STATE WITH NO g ON THE AIRPLANE. ...LL CHANGES IN THE NOSE ATTITUDE IN THIS ...TION FELT FAIRLY REASONABLE. HOWEVER, ... g IS APPLIED TO THE AIRPLANE, CONTROL ...ES VERY DIFFICULT. IT WAS IMPOSSIBLE IN ... OR IN A SYMMETRICAL PULL-OUT TO MAIN... A STEADY g.	IT WAS IMPOSSIBLE TO STAY WITH THE NEEDLE ALL THE TIME IN THE STEP TRACKING TASK. I WAS UNABLE TO JUDGE HOW MUCH OVERSHOOT TO ANTICIPATE SO I COULDN'T CHECK THE PITCH RATE TO STOP THE NOSE WHERE I WANTED IT. I HAD TO SETTLE FOR SOMETHING CLOSE. IF I TRIED TO TIGHTEN THE CONTROL LOOP I FOUND THE OSCILLATIONS JUST BECAME LARGER. WITH THE RANDOM INPUTS, YOU JUST COULD NEVER REALLY PIN THE NEEDLE DOWN. YOU WERE CONSTANTLY CHASING IT AND ALWAYS OUT OF PHASE WITH IT.	NO COMMENTS		THE TENDENCY TO OVER G THE AIRPLANE IN PULL OUTS AND ROLLING INTO TURNS. THE PIO TENDENCY WHEN YOU ARE TRYING TO MAINTAIN A CERTAIN g.	THE MOTIONS CANNOT BE ELIMINATED BY JUST SACRIFICING TASK PERFORMANCE. I HAVE TO REDUCE MY GAIN CONSIDERABLY TO KEEP THE g OSCILLATION AT A LOW LEVEL. I'LL RATE IT A PIOR OF 4. I'LL RATE THE AIRPLANE AS UNACCEPTABLE MAINLY BECAUSE OF THE TENDENCY TO OVERSTRESS THE AIRPLANE ON PULL OUTS. I DON'T THINK IT IS BAD ENOUGH TO BE CONTROLLABLE WITH DIFFICULTY AND REQUIRING SUBSTANTIAL SKILL AND ATTENTION TO RETAIN CONTROL. I'LL RATE IT A B-7.
... AS ABOVE	SAME AS ABOVE.	NO COMMENT.	NONE.	SAME AS ABOVE.	I WOULD RATE THIS A PIOR OF 4. WE STILL HAVE THE SAME TENDENCIES AS NOTED BEFORE I PICKED THE STICK FORCE. I WOULD NOW BUY THE AIRPLANE, BUT I WOULD BUY IT VERY RELUCTANTLY BECAUSE IT IS STILL NOT A GOOD AIRPLANE. YOU COULD DO THE MISSION BUT ALL THE THINGS I MENTIONED BEFORE WOULD NEED FIXING. I'LL RATE IT A-4.
...E ATTITUDE CONTROL FOR MEDIUM GAIN INPUTS ...T TOO BAD. NORMAL ACCELERATION CONTROL ...T BAD IF YOU EASE INTO THE DESIRED g. ...U PULL TO A VALUE OF g QUICKLY YOU'LL ...WO OF THOSE OVERSHOOTS BEFORE IT SETTLES ...	IN BOTH OF THE TRACKING TASKS, IT WAS NEXT TO IMPOSSIBLE TO STAY ON THE NEEDLE ALL THE TIME. AGAIN, IF YOU TRY TO TRACK VERY TIGHTLY YOU SEE THIS OSCILLATORY TENDENCY.	THE CONTROL IN THE PRESENCE OF RANDOM DISTURBANCES WAS DIFFICULT. THE TRACKING CAPABILITY DETERIORATED GREATLY. IT WAS QUITE DIFFICULT TO REALLY KEEP THE NOSE ON A TARGET.	THE INITIAL RESPONSE IS FAIRLY NICE.	THE OSCILLATORY TENDENCY WHEN YOU ARE TRYING TO TRACK PRECISELY, AND THE LIGHT STICK FORCES ARE OBJECTIONABLE.	THERE ARE UNDESIRABLE MOTIONS INDUCED WHEN YOU INITIATE ABRUPT MANEUVERS, BUT THEY CAN BE ELIMINATED BY DECREASING YOUR GAIN. IT IS A SOLID PIOR OF 2. I HAVE TO DOWNRATE THIS AIRPLANE BECAUSE OF THE STICK FORCE PER g, THEY DO NOT PROVIDE STRUCTURAL PROTECTION. FOR THIS REASON ALONE, THE AIRPLANE IS UNACCEPTABLE. IF THE STICK FORCES WERE BEEFED UP A LITTLE THE AIRPLANE WOULD BE SATISFACTORY. I'LL RATE IT A B-7. THE AIRPLANE IS NO LONGER UNACCEPTABLE. I WOULD LIKE TO SEE THIS BOBBLING TENDENCY FIXED. I THINK IT FITS INTO THE A-5 CATEGORY.
...SLUGGISH RESPONSE MAKES IT DIFFICULT ...QUIRE A PARTICULAR ATTITUDE, BUT ... YOU'VE ATTAINED THE DESIRED ATTI... THE AIRPLANE IS FAIRLY SOLID.	IN THE ATTITUDE TRACKING TASKS, YOU JUST COULDN'T DO ANYTHING RAPIDLY. IT WAS VERY DIFFICULT TO CHASE THE NEEDLE IN THE STEP INPUT TASK. IN THE RANDOM NOISE TASK IT WAS IMPOSSIBLE TO KEEP THE NEEDLE CENTERED.	THE CONTROL IN THE PRESENCE OF THE RANDOM DISTURBANCES WAS A BIT MORE DIFFICULT. IT DID DEGRADE YOUR PERFORMANCE SOMEWHAT IN THAT IT TENDED TO GET A LITTLE MORE OSCILLATORY WHEN YOU TRIED TO TRACK IN THE PRESENCE OF THE DISTURBANCES.	THE AIRPLANE WAS VERY STEADY ONCE YOU GOT IT ON A TARGET.	THE TENDENCY TO BOBBLE AND THE HEAVY STICK FORCES WERE OBJECTIONABLE.	THE AIRPLANE HAS A BOBBLING TENDENCY, BUT ONLY WHEN YOU ARE ATTEMPTING VERY TIGHT CONTROL. I'LL RATE IT A PIOR OF 1.5. I WOULD NOT BUY THE AIRPLANE BECAUSE THE STICK FORCES ARE TOO HEAVY. ALSO THE AIRPLANE'S SLUGGISH RESPONSE NEEDS TO BE FIXED. THE AIRPLANE JUST DOESN'T HAVE ENOUGH MANEUVERABILITY. I'LL RATE IT A B-7.
...E ATTITUDE CONTROL, IF YOU EASE INTO A ...T WITH NO SUDDEN LAST MINUTE CORRECTIONS, ...PRISINGLY GOOD. YOU MAY SEE SOME ...CY TO BOBBLE JUST SLIGHTLY, HOWEVER, ... YOU TIGHTEN THE LOOP AND MAKE FAST, ...T INPUTS, THE OSCILLATIONS GET WORSE. ...L ACCELERATION IN THE STEADY STATE IS ...IVELY STABLE. THERE IS A TENDENCY TO ... THE AIRPLANE IN A PULL-UP WITHOUT ...ZING IT.	THE PERFORMANCE DURING THE DISCRETE STEP TRACKING TASK WAS FAIR. IF YOU WOULD PURPOSELY EASE OFF ON YOUR CONTROL GAIN YOU COULD TRACK FAIRLY WELL. YOU WOULD USUALLY GET A BOBBLE OR TWO. THEN THINGS STEADIED OUT. FOR THE RANDOM INPUT TASK THE ONLY THING YOU COULD DO WAS TO JUST REDUCE YOUR GAIN AND TRY TO AVERAGE OUT THE ERRORS.	I DIDN'T FEEL THAT MY TRACKING CAPABILITY WAS REDUCED VERY MUCH BY THE RANDOM DISTURBANCES.	THE INITIAL RESPONSE WAS GOOD. ONCE YOU BECAME SQUARED AWAY ON THE TARGET THE AIRPLANE WAS FAIRLY STEADY.	THE TENDENCY TO OVERSTRESS THE AIRPLANE, AND THE BOBBLING TENDENCY ARE BAD FEATURES.	FOR THE PIOR, I THINK IT'S NOT QUITE AS BAD AS A 3 BUT WORSE THAN A 2 SO I'LL RATE IT A 2.5. THE AIRPLANE IS UNACCEPTABLE BECAUSE WITH THE COMBINATION OF STICK FORCES AND AIRPLANE DYNAMICS THAT WE HAVE THERE IS A GREAT TENDENCY TO OVER G THE AIRPLANE. FOR THIS REASON I'LL RATE IT A B-7. THE RATING, BASED ON THE MISSION WHERE THERE WOULDN'T BE ANY FIGHTER TYPE MANEUVERING, IS AN A-4.

B

REFERENCES

1. Chalk, C.R., Neal, T.P.; Harris, T.M.: Recommendations for Revision of MIL-F-8785(ASG) "Military Specification - Flying Qualities of Piloted Airplanes." Submitted March 1967, revised May 1968, to be published.

2. DiFranco, D.A.: Flight Investigation of Longitudinal Short-Period Frequency Requirements and PIO Tendencies. AFFDL-TR-66-163, April 1967.

3. Chalk, Charles R.: Additional Flight Evaluations of Various Longitudinal Handling Qualities in a Variable Stability Jet Fighter. Part 1 - WADC TR 57-719 (CAL Report No. TB-1141-F-1), March 1958.

4. Chalk, Charles R.: Additional Flight Evaluations of Various Longitudinal Handling Qualities in a Variable Stability Jet Fighter. Part 2 - WADC TR 57-719 (CAL Report No. TB-1141-F-2), July 1958.

5. Harper, Robert P. Jr.: Flight Evaluations of Various Longitudinal Handling Qualities in a Variable-Stability Jet Fighter. WADC TR 55-299 (CAL Report No. TB-757-F-12), July 1955.

6. Chalk, C.R.: Fixed-Base Simulator Investigation of the Effects of L_α and True Speed on Pilot Opinion of Longitudinal Flying Qualities. ASD-TDR-63-399, November 1963.

7. Jex, H.R., Cromwell, C.H.III: Theoretical and Experimental Investigation of Some New Longitudinal Handling Qualities Parameters. ASD-TR-61-26, June 1962.

8. Kehrer, W.T.: Longitudinal Stability and Control of Large Supersonic Aircraft at Low Speeds. ICAS Paper No. 64-586, August 1964.

9. Shomber, H.A., Gertsen, W.M.: Longitudinal Handling Qualities: An Evaluation. AIAA Paper No. 65-780.

10. Newell, Fred; Campbell, Graham: Flight Evaluations of Variable Short Period and Phugoid Characteristics in a B-26. WADC TR 54-594 (CAL Report No. TB-757-F-11), December 1954.

11. Malcom, L.G., Tobie, H.N.: A New Short-Period Handling Quality Criterion for Fighter Aircraft. Boeing Document D6-17841 T/N, September 1965.

12. Bihrle, W., Jr.: A Handling Qualities Theory for Precise Flight Path Control. AFFDL-TR-65-198, June 1966.

13. Harper, Robert P., Jr., Cooper, George E.: A Revised Pilot Rating Scale for the Evaluation of Handling Qualities. CAL Report No. 153, September 1966.

14. Key, David L.: A Functional Description and Working Data for the Variable-Stability System T-33 Airplane. CAL Report No. TC-1921-F-2, October 1965.

15. Parrag, Michael L.: Pilot Evaluations in a Ground Simulator of the Effects of Elevator Control System Dynamics in Fighter Aircraft. AFFDL-TR-67-19 (CAL Report No. TC-2083-F-2), September 1967.

16. DiFranco, Dante A.: In-Flight Investigation of the Effects of Higher-Order Control System Dynamics on Longitudinal Handling Qualities. Submitted April 1968, to be published as AFFDL-TR-68-90 (CAL Report No. BM-2238-F-4).

17. Behm, Dennis D.: Analog Matching Technique for Longitudinal Responses. CAL Flight Research Memorandum No. 409, October 1967.

18. A'Harrah, R.C.: Maneuverability and Gust Response Problems Associated With Low-Altitude, High Speed Flight. AGARD Report 556, October 1967.

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13 ABSTRACT

The results of an in-flight investigation of the short-period handling qualities requirements for the up-and-away portion of the mission of a wheel-controlled airplane with a low to medium load factor are reported and discussed. Two groups of configurations with constant short-period damping ($\zeta_{sp} \simeq .7$) but different n_z/α's and $1/T_{\theta_2}$'s were investigated. A brief study was conducted to determine the effect on the airplane handling qualities of variations in stick motion per normal acceleration and the PIO tendencies resulting from a reduction in short-period damping from $\zeta_{sp} \simeq .7$ to $\zeta_{sp} \simeq .1$. The results are presented in terms of pilot rating and pilot comment data. Comparisons with the proposed Recommendations for Revision of MIL-F-8785(ASG) "Military Specification - Flying Qualifies of Piloted Airplanes" are made and the data is correlated with various suggested short-period handling qualities criteria. The vehicle used for the in-flight evaluation was a three-axis variable stability T-33 equipped with a wheel controller.

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14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

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